

# **EARLY WARNING SYSTEM GUIDANCE TO MITIGATE FLASH FLOOD IMPACTS IN PETRA REGION, JORDAN**

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## **Dedication**

This research is dedicated to my late father and late mother, and to my lovely wife and daughters

## **Declaration**

This thesis is submitted under the University of Salford requirements for the award of a PhD degree by research. Some research findings were published in refereed journal and as refereed conference papers prior to the submission of the thesis during the period of PhD studies.

The researcher declares that no portion of the work referred to in the thesis has been submitted in support of an application for another degree of qualification to the University of Salford or any other institution.

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Hussein Alhasanat

## Abbreviation

APFM	: The Associated Programme on Flood Management
CRED	: Centre for Research on the Epidemiology of Disasters
CWA	: Clean Water Act
DRM	: Disaster Risk Management
DRMPA	: Disaster Risk Management Profile - Amman
DRR	: Disaster Risk Reduction
EC	: European Communities
EM-DAT	: OFDA/CRED International Disaster Database
EWEs	: Extreme Weather Events
EWS(s)	: Early Warning System(s)
FFWSG	: Flash Flood Early Warning System Guidance
FRM	: Flood Risk Management
GDP	: Gross domestic product
ISDR	: International Strategy for Disaster Reduction
MENA	: Middle East and North Africa
MRI	: Mortality Risk Index
NDC	: National Disaster Centre
NDRMP	: The National Disaster Response Master Plan
NOAA	: National Oceanic and Atmospheric Administration
PDTRA	: Petra Development & Tourism Region Authority
RM	: Risk Management
SAS	: Statistical Analysis System
UNDP	: United Nations Development Program
UNISDR	: United Nations International Strategy for Disaster Reduction
WADI	: Drainage courses formed by water, but are distinguished from river valleys or gullies in that surface water is intermittent or ephemeral
WB	: World Bank
WHO	: World Health Origination

## **Glossary of Terms**

<b>Affected</b>	Number of people requiring immediate assistance during a period of emergency; this may include displaced or evacuated people.
<b>Contingency planning</b>	A management process that analyses specific potential events or emerging situations that might threaten society or the environment and establishes arrangements in advance to enable timely, effective and appropriate responses to such events and situations
<b>Disaster</b>	A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources
<b>Disaster Risk</b>	The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period
<b>Disaster risk management</b>	The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.
<b>Disaster risk reduction</b>	The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events
<b>Early Warning Systems</b>	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.
<b>Estimated damage</b>	Global figure of the economic impact of a disaster; it is given in current US dollars.

<b>Exposure</b>	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest. It is essential to define the elements of disaster to understand the term “disaster” and how do these elements estimate the quantitative risks associated with that hazard in the area of interest.
<b>Flood risk</b>	The product of flood hazard and society’s vulnerability to floods and exposure or product probability to flood and its consequences.
<b>Hazard</b>	A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage
<b>Homeless</b>	Number of people whose house is destroyed or heavily damaged and therefore need shelter after an event
<b>Injured</b>	Number of people suffering from physical injuries, trauma or an illness requiring immediate medical treatment as a direct result of a disaster.
<b>Land-use planning</b>	The process undertaken by public authorities to identify, evaluate and decide on different options for the use of land, including consideration of long term economic, social and environmental objectives and the implications for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses.
<b>Mitigation</b>	The lessening or limitation of the adverse impacts of hazards and related disasters. Mitigation measures encompass engineering techniques and hazard-resistant construction as well as improved environmental policies and public awareness. It should be noted that in climate change policy, “mitigation” is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change.

<b>Natural Hazard</b>	Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.
<b>Non-structural measures</b>	Any measure not involving physical construction that use knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education
<b>Planning for various disasters</b>	Two strategies for disaster planning include the agent-specific and the all-hazards approaches. In agent-specific planning, communities only plan for threats most likely to occur in their region. Since many disasters pose similar problems and similar tasks, an all-hazards approach involves planning for the common problems and tasks that arise in the majority of disasters
<b>Preparedness</b>	The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions
<b>Prevention</b>	The outright avoidance of adverse impacts of hazards and related disasters
<b>Recovery</b>	The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors
<b>Relief (emergency management)</b>	The process of responding to a catastrophic situation, providing humanitarian aid to persons and communities who have suffered from some form of disaster.
<b>Resilience</b>	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions
<b>Response</b>	The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health

impacts, ensure public safety and meet the basic subsistence needs of the people affected

**Risk** The possibility of harmful consequences or expected losses resulting from interactions between natural or human-induced hazards and vulnerable conditions. It is “the combination of the probability of an event and its negative consequences”

**Risk assessment** A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

**Risk management** The systematic approach and practice of managing uncertainty to minimize potential harm and loss.

**Risk mitigation (flood)** A selective application of options (both structural and non-structural) to reduce either likelihood of a flood or its adverse consequences, or both.

**Structural measures** Any physical construction to reduce the chance or severity of the flood waters reaching a receptor. Structural measures range from large-scale infrastructure responses, such as barriers and levees, through to local responses to improve the resistance and resilience of individual homes or critical installations

**Total affected** Sum of injured, homeless and affected.

**Total deaths** Number of people who lost their life because the event happened (it includes also the missing people based on official figures).

**Victims** Sum of total deaths and total affected.

**Vulnerability** The potential for loss (human, physical, economic, natural, or social) due to a hazardous event. It is the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard



## **ABSTRACT**

The frequent occurrence of natural disasters; especially flash floods, are resulting the significant threats to many countries around the world. The truth that cannot be ignored, is that the effects of flash floods on the developing countries' societies and economies are massive, compared with developed countries. Petra region; which is located in Jordan, is exposed to flash flood risks, which led to losses in lives, public and private properties. While the frequencies and impacts of flash floods might not be controlled easily, the need for more effective early warning systems has become extremely important. United Nations International Strategy for Disaster Reduction (UNISDR) and many researchers assumed that if an effective tsunami early warning system had been in place in the Indian Ocean region on 26 December 2004, thousands of lives would have been saved. Accordingly, Petra Region's communities have experienced the impacts of flash floods in recent years due to absence of early warning systems and the lack of knowledge among communities about flash flood risks. These problems provide the context and demonstrate the significance of this study. Research aims to develop a responsive Flash Flood Early Warning System Guidance (FFEWSG) to enhance resilience in Petra Region.

This research takes the social constructivism (interpretivism) stance in the continuum of philosophy and adopts a case study research strategy with qualitative method of research techniques. The research data collection was conducted in three phases. During the first phase, pilot semi structured interviews were conducted among people in Petra Region while the second phase focused on collecting the data from disaster affected communities, and disaster experts using semi-structured interviews. The third phase gathered information from Petra Development and Tourism Region Authority (PDTRA) documents. Data was analysed using content analysis. The research investigated flash floods in developed and developing countries; reviewed previous reports of flash flood events in Petra Region and how they affect the study area; and current early warning systems related to flooding. The research recommended a flash flood early warning system that could empower the local governmental institutions to mitigate flash flood impacts and enhance the resilience in Petra Region. It is expected that the research will add significant empirical evidence on the elements of the guidance within early warning system for flash flood, and will provide a useful tool in Petra Region for stakeholders, particularly for the government or the implementing agencies, helping to ensure the success of reducing the flash flood risks by the development of FFEWSG.

# Chapter 1 Introduction

## 1.1 Research Background

The world has witnessed in recent years increases in the intensity and frequency of natural disasters (EM-DAT, 2015). Large-scale disasters regularly affect societies over the globe, causing huge destruction and damage, which can impose drastic consequences both directly and indirectly on people's lives and their livelihoods. Nevertheless, they are considered as open windows of opportunity for creating communities that are more resilient (Ingirige *et al.*, 2008). Within the last four decades (1970-2010) natural disasters have caused more than 3.3 million deaths (or 82,500 a year), and costed 2.3 trillion dollars (1970-2008) in economic damages (WB, 2010), which is 0.23 percent of cumulative world output.

Natural disasters have resulted in significant economic and human loss for millennia (Noy, 2009). In 2013, 330 natural triggered disasters were registered, which killed a significant number of people (21,610) with 96.5 million people affected worldwide, (CRED, 2013). UNISDR (2015) reported that economic losses from disasters are now reaching an average of US\$250 billion to US\$300 billion each year. Future losses (expected annual losses) are now estimated at US\$314 billion in the built environment alone. Therefore, it is crucial to adopt more mitigation measures to decrease these losses especially in the developing countries.

One category of natural hazard, flash floods, rarely garners that level of attention. Yet according to the World Meteorological Organization (WMO), flash floods are the most lethal form of natural hazard (based upon the ratio of fatalities to people affected), and cause millions of dollars in property damage every year (WMO, 2007). This is because flash floods tend to occur frequently but at a very small scale. Moreover, flash floods often impact poorer populations in remote locations. Individually they rarely capture news headlines, but cumulatively they can severely undermine a region's development (NOAA, 2010).

The number of flash flood events has increased significantly all around the world over the last three decades. While the number of fatalities per flood events markedly decreased since the year 2000 despite the significant increase in the number of floods (Parker *et al.*, 2007). It has increased in the developing countries due to lack of preparedness and mitigation measures. For example, the Indian Ocean tsunami caused the highest death toll from floods (Gencer, 2013).

According to WB (2014), floods represent one of the most serious challenges to growth and stability in the Middle East and North Africa (MENA). Over the last 30 years (1981–2011), floods have been

the most recurrent disasters recorded in EM-DAT, with at least 300 events (53 percent of the total number of disasters), indicating a strong need for early warning systems. Furthermore, many of the urban poor in Africa face growing problems of severe flooding (Douglas *et al.*, 2008). Increased storm frequency and intensity related to climate change are exacerbated by such local factors as: the growing occupation of floodplains, increased runoff from hard surfaces, inadequate waste management, and silted up drainage. Moreover; the vulnerability to floods has increased in Africa during the recent decades.

In the Asian region, millions of people's lives are affected yearly by natural hazards such as flooding, typhoons and droughts. In the recent years, a number of natural hazards has struck the Asian region; of all the huge disasters that claimed the lives of thousands the Indian Ocean tsunami in 2004 was the largest, estimated to have killed more than 230,000 people (Falk, 2015). The lack of a tsunami warning system in the Indian Ocean contributed to the severity of the 2004 Indian Ocean tsunami (Satake *et al.*, 2007). In 2011 the so-called triple disaster in Japan struck, with an earthquake followed by tsunami, which triggered the nuclear power plant disaster that caused 20,000 people's deaths and in 2013, Typhoon Haiyan killed about 7,800 people in the Philippines (Falk, 2015).

Jordan, a country within the Middle East Region, is no exception when it comes to exposure to hazards. It is exposed to diverse natural hazards and disaster risks. Key amongst them includes earthquakes, droughts, flash floods and desertification. Climatic hazards pose a set of threats to Jordanian economic and human development, particularly the flash flooding. In particular, parts of the country face severe localized flash flooding. Flash flooding has historically caused damages to local tourist infrastructure, archaeological sites and urban infrastructures (UNDP, 2011). In the past half century, incidents of flash flooding in Jordan have claimed the lives of 345 persons and affected 24,321 lives. Additionally, floods usually leave vast agricultural areas covered with heavy water (UNDP, 2009).

Historic records and rainfall-runoff data in southern Jordan indicate that large flash floods occurred frequently in the past century (Al-Qudah, 2011). On November 2014, at least three people have died in flooding affecting the north west of Jordan, and 54 people were injured in separate incidents after they were trapped by floodwater in different areas in Jordan (Richard, 2014). November 2015 witnessed a heavy rain storm of about 40 minutes flooded streets in Amman-Jordan that has led to four deaths, and high cost damages estimated by JOD 5 million, water level reached more than 2.5 m in street tunnels, and about 80 cm in the main roads (Noghai, 2015).

Flash floods pose a serious threat to the tourist and local activities in Jordan as well as to the monuments themselves. Due to this, hydrologists ranked it as the Wadi – a drainage course formed by water, but is distinguished from river valleys or gullies in that surface water is intermittent or ephemeral- with the highest risk/damage in Jordan (Al-Weshah & El-Khoury, 2001). However, the flash floods in the area do not occur every year. Nevertheless, at certain years the extent of flash flood can be huge (2.42m<sup>3</sup>/sec was recorded as maximum mean daily discharge during 1963). Flash floods may be hydraulically categorized as hybrid of debris and turbid flows. The 1963 and the 1991 flash floods are the most extreme events that hit the ancient city of Petra (Al-Weshah & El-Khoury, 1999). The flood that occurred in April, 1963 was an extreme event, probably with a 100-year return period, eyewitnesses stated that the height of the floodwater was about 10 metres, despite the great emergency efforts, twenty French tourists lost their lives (Al-Weshah & El-Khoury, 1999). Therefore; flash floods have historically caused a major threat to the Wadi Mousa city in Petra Region.

Similarly, historical records concerning flash floods threatening Petra, south Jordan, have shown that flood protection and mitigation measures are urgently needed to protect tourists and the existing monuments (Al-Weshah & El-Khoury, 1999). One of these measures is establishing a local mechanism that helps make pro-active climate information available to support better preparedness and resilient planning (Hoedjes *et al.*, 2014).

This research aims to develop appropriate Flash Flood Early Warning System Guidance (FFEWSG) to enhance resilience in Petra Region, and investigate the potential, scientific and practical benefit of the system in the study area. This will help to provide an early warning of an approaching flood to local governmental institutions, local communities in the flood-prone areas giving them sufficient time to take necessary preparations before the arrival of flood, aiming to enhance their capacities to reduce flash flood risk and enhance resilience in Petra region.

## **1.2 Research problem**

The previous literature has highlighted the threats posed by flash flood in the whole world in general, and Jordan and Region of Petra in particular. To reduce these threats, a crucial need is to find mitigation tools to enhance local governmental institutions and local communities' preparedness in the pre-disaster in adequate and active way to avoid the risks of the flooding in the area and protect lives and properties.

Because flash floods can even occur when there is no rain in the immediate area, early warning systems and preparedness are critical to saving lives (NOAA, 2010). Flash Flood Early Warning System is a tool that might be a responsive to warn local authorities and communities and enhance their capacities to reduce flash flood risk. Having identified the need for this tool, it is useful to look at how it should be designed to contribute to disaster risk reduction in tourist sector and economic development in Petra Region.

Due to insufficient planning and preparedness; such as early warning systems, and mitigation measures; such as building capacities and awareness; that have been adopted by the local governmental authorities in the region, Petra region has been exposed over many decades to flash flood risks (see Appendix G flash floods inventory for Petra Region 1966-2013). Based on this background, the research problem that is investigated is to explore the development of a flash flood early warning system guidance that might enhance the local authorities and communities to mitigate flash flood risks in study area. Therefore, researcher finds it is crucial to conduct this study, with particular reference to the early warning systems related to flooding. Furthermore, validate this tool within the Petra region flash flood mitigation system aiming to enhance region's resilience.

In the Hyogo Framework for Action (2005-2015), it is stated that saving lives depends on functioning early warning systems and therefore on local early warning centres that have the capacity to respond immediately to nationally broadcast early warnings or pick up on local warning messages. This requires dedicated financial and human resources to ensure continuous functioning of the centre.

The NOAA (2010, p. 73) stated that the important technical elements of the flash flood guidance system are: (I) Development and use of the bias-corrected satellite precipitation estimate field; (II) Use of physically-based hydrologic modelling to determine flash flood guidance and flash flood threat.

The proposed flash flood early warning system guidance (FFEWSG) to be developed in this research, is to guide the local authorities to address the reduction and mitigation in devastation caused by flash floods in terms of reductions in the loss of life, people affected and property damage. The system concentrates at the: (i) preparedness; i.e. risk knowledge and weather monitoring (ii) mitigation; issue warning, dissemination (iii) response; i.e. react to warning, activate contingency and emergency plan.

Some of system component are existing, but will need to be modified where required and how they should perform. The non-existing components will be added to fulfil the aim of this study.

If the FFEWSG is implemented, the beneficial parties will be local government, local communities, public security, civil defence, and Petra visitors. The FFEWSG will enhance communities' preparedness and region's resilience.

### **1.3 Aim and Objectives**

The aim of this research is to develop a Flash Flood Early Warning System Guidance (FFEWSG) in the study area to enhance resilience. The following objectives were formulated to facilitate accomplishment of the aim of the research:

1. To explore the key determinant of flash floods in developed and developing countries.
2. To review the specific factors that contribute to flash flood events in Petra Region and their impacts at the study area.
3. To critically review the best practices of early warning systems related to flooding.
4. To identify elements for an effective early warning system guidance for flash flood.
5. To develop a guidance to a responsive early warning system for flash flood in the study area.

### **1.4 Research questions**

To accomplish the above research objectives, the following research questions are formulated:

1. How do flash flooding events affect countries in the world in general?
2. How did flash flood events affect Petra Region in Particular?
3. What are the best practices adopted by countries prone to floods to mitigate the impacts?
4. How can guidance of a responsive EWS for flash floods be developed? What are the empirical elements of the guidance within early warning system for flash flood?

### **1.5 Knowledge Gaps and Contribution to Knowledge**

#### **1.5.1 General theoretical gap and the specific gap**

Flash flood early warning system is of interest not just to Petra region, but also to many regions and countries. Flash floods can be dangerous and destructive in almost any part of the world. Despite the significance of flash flood events, few countries have implemented flash flood warning systems. This is due in part to the technical complexity of predicting flash flood events with enough confidence (accuracy) and lead-time (advance warning) to take precautionary action (NOAA, 2010,

p. 17). Early warning systems are crucial to saving lives. They can be particularly effective at reducing fatalities, notably due to the effectiveness and low cost of evacuating for a flash flood (Hoedjes *et al.*, 2014). Natural hazards turn into disasters if the affected people cannot cope with them. A community without early warnings will be unprepared and will suffer from the full-blown damages inflicted by the hazard (Jacks *et al.*, 2010).

Despite discussing EWS (guidance or model) by many researchers (see section 2.6) and experts (Abdelkhalek, 2011; Al-Qudah, 2011; Antonio *et al.*, 2012; Barbetta *et al.*, 2006; Cools *et al.*, 2009; Franchini & Lamberti, 1994; Lamberti & Pilati, 1996), or United Nations agencies (ISDR, 2009b; NOAA, 2010), there are theoretical and practical gaps in knowledge that can be bridged within this research.

Some of these gaps tend to appear especially within the available literature that lacks coverage on areas such as: early warning system for flash flood guidance, and empirical evidence to inform the elements of the guidance process within early warning systems for flash flood. These gaps could be summarised as follows:

#### **1.5.2 Gaps in theoretical knowledge:**

- Theoretical and practical gaps in the available literature about early warning system for flash flood guidance.
- Lack of literature to cover the empirical evidence on the elements of the guidance within early warning system for flash flood.

#### **1.5.3 Practical gaps in Petra Region**

- Lack of literature about flash floods impacts in the Petra Region and how to reduce these impacts.

#### **1.5.4 Contribution to Knowledge**

The main contribution to theory from this research will be the provision of an in-depth empirical evidence on the elements of the tool within early warning system for flash flood. In addition, this study develops a guidance to a responsive early warning system for flash floods (FFEWSG) in Petra Region. The research seeks to bridge that gap in literature about flash flood events and their impacts in study area. The study contributes to practice by providing a useful tool in Petra Region for stakeholders, particularly for the government or the implementing agencies, helping ensure the success of reducing the flash flood risks by the development of FFEWSG. The above contributions reflect the novelty of this research. The contribution to knowledge arising from the study is further discussed in section 7.4.

## **1.6 Structure of the Research**

The structure of the thesis is as follows:

- **Chapter 1: Introduction**

This chapter introduces the background knowledge of this research, research problem, aim and objectives, research questions, the contribution to knowledge, and thesis structure.

- **Chapter 2: Literature Review on Disasters and Flash Flooding**

A literature review pertaining to the study is provided, presenting the impacts of disasters, flood and flash floods in developed, developing countries in general and Jordan and Petra in Particular, disaster risk management, and early warning systems related to flooding.

- **Chapter 3: Conceptual Framework**

This chapter has presented the conceptual framework adopted by researcher. It started by introducing the achieved work in conceptual framework, and what is intended to achieve. Then it presents the need for a conceptual framework, the main issues of the conceptual framework; the importance of EWS for flash flood guidance, the concept of the community-centred EWS for flash floods, the need to warn local authorities and communities in Petra Region, and the need for developing the guidance. After that, the chapter presents the development of the conceptual framework including the main concepts, the interrelation, and the boundary. Finally, the conceptual framework was presented.

- **Chapter 4: Research Methodology**

This chapter outlines the research methodological design and discusses the philosophical assumption of the research. It also shows the adopted approach, strategy, techniques, and the data collection and analysis.

- **Chapter 5: Data Analysis and Results**

This chapter presents the findings from the research, examples of data analysis and presentation of evidence to support unique contribution. It also describes the primary work ideas, theories of framework, interviews together with the results as relevant to research objectives. It also shows the findings of the analysed data.

- **Chapter 6: Final Framework**

This chapter presents the final framework after data analysis and validation. It presents the definition of the Flash Flood Early Warning System Guidance, the factors that determine the benefits



of EWS's, and the advantages of EWS's. It also shows the refinement of the final framework for the guidance and its stages of development and approaches.

- **Chapter 7: Conclusion**

This chapter summarises the main findings from research for each objective of the study, describes the novelty and contribution of research to theory and practice, the limitations of research, and suggests some areas for further research.

## **Chapter 2      Literature Review on Disasters and Flooding**

### **2.1 Introduction**

This chapter begins with some terminology relating to disasters, types of disasters, impacts of the disasters, floods and flash floods and their impacts at both developed and developing countries in general including recent experience, Jordan and Petra region in particular. Then, this chapter presents the disaster risk management, the life cycle of disaster management and flood risk management. Moreover, it analyses the frequency of flood and flash floods occurrence in world countries during the past forty years, between 1970 and 2014, and the impacts on people, economy and the infrastructure sector. Section 2.4.1 concentrated on early warning systems, benefits of EWS's, and examples at EWS projects related to flooding. Moreover, some EWS's projects were presented aiming to shed light on their effects on reducing flash flood risks. This chapter is finally concluded in section 2.6. In addition, it is intended to find out the theoretical gaps in the available literature and practical gaps in the study area.

### **2.2 Disasters**

A disaster can be ostensibly defined as any tragic event stemming from events such as earthquakes, floods, catastrophic accidents, fires, or explosions. It is a phenomenon that can cause damage to life and property and destroy the economy, social and cultural life of people (Reviews, 2016). Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation (ISDR, 2009a). Developing countries suffer the greatest costs when a disaster hits: more than 95 percent of all deaths caused by disasters occur in developing countries, and losses due to natural disasters are 20 times greater (as a percentage of GDP) in developing countries than in industrialized countries (Birkmann, 2007).

Disasters are broadly divided into two types comprising natural and man-made (technological) disasters (Sena & Michael, 2006). CRED (2014) stated that natural disaster can be categorised into six sub-groups; geophysical, meteorological, hydrological, climatological, biological and extraterrestrial (Table 2.1 shows natural disasters sub-groups and their definition); which in turn cover 14 disaster types and more than 30 sub-types (see figure 2.1).

Table 2.1: Natural disasters subgroups definition and classification

Disaster Subgroup	Definition
<b>Geophysical</b>	A hazard originating from solid earth
<b>Meteorological</b>	A hazard caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days
<b>Hydrological</b>	A hazard caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater
<b>Climatological</b>	A hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability
<b>Biological</b>	A Hazard caused by the exposure of living organisms to germs and toxic substances or vector-borne diseases that they may carry
<b>Extraterrestrial</b>	A hazard caused by asteroids, meteoroids, and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earth, and by changes in interplanetary conditions that effect the Earth's magnetosphere, ionosphere, and thermosphere.

(Source: Adopted from EM-DAT, 2014)

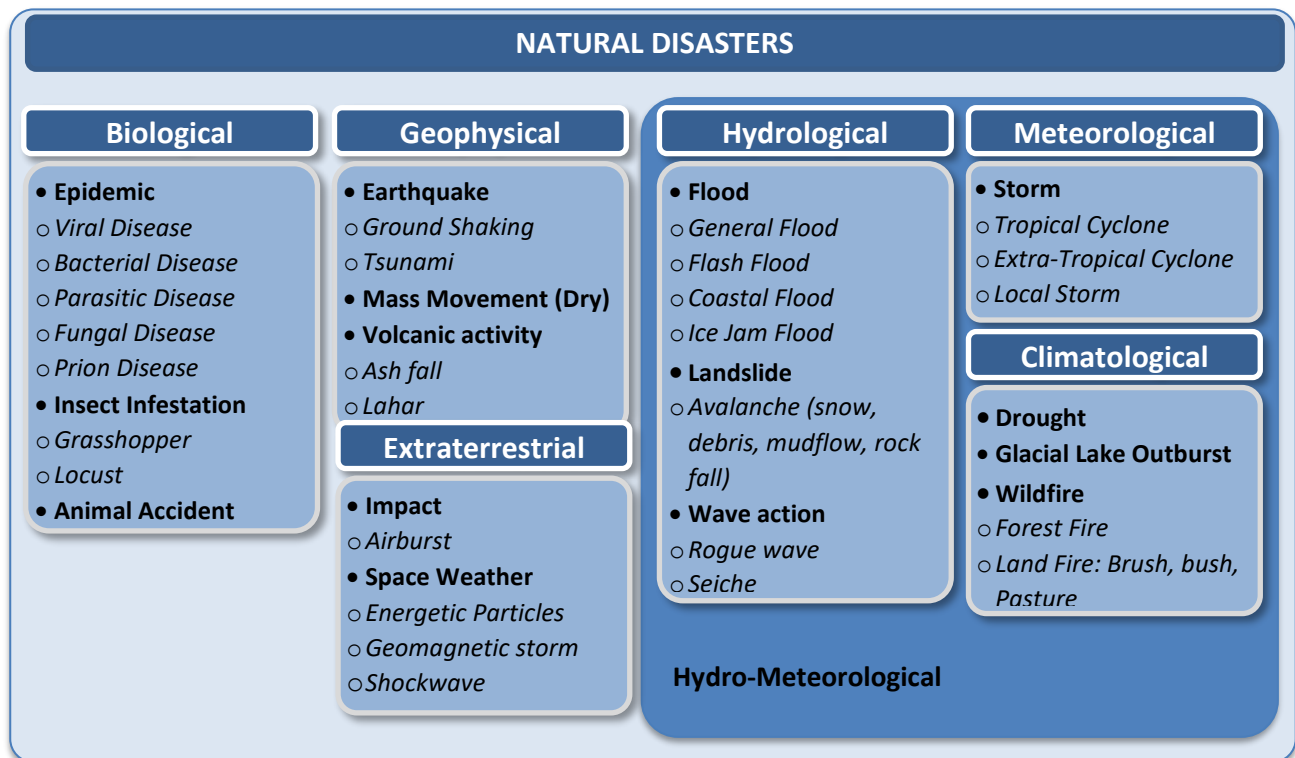


Figure 2.1: Natural disaster classification

(Source: Adopted from EM-DAT (2014))

The second type of disaster classified by cause man-made (technological) disasters. Depending on discipline, man-made disaster is defined as “disaster created by man, either intentionally or by accident” (Chan, 2017). Man-made disaster is a broad category that characterised by the presence of human factors as a cause of the event, or results as consequence of human error or breakdown of technological systems, which can be categorised into: industrial accidents, transport accidents

and miscellaneous accidents (Table 2.2 shows man-made disasters definitions and their sub-groups); which in turn cover 15 sub-types (see Figure 2.2).

Table 2.2: Man-made disasters subgroups definition and classification

<b>Disaster Subgroup</b>	<b>Definition</b>
<b>Industrial accident</b>	A hazard caused by industrial accidents such as: caused by collapse, explosion, fire, gas leak, poisoning, radiation, and other.
<b>Transport accident</b>	A hazard caused by transport accidents in air, rail, road and water
<b>Miscellaneous accidents</b>	A hazard caused by miscellaneous accidents such as collapse, explosion, fire, and other

(Source: Chan, 2017)

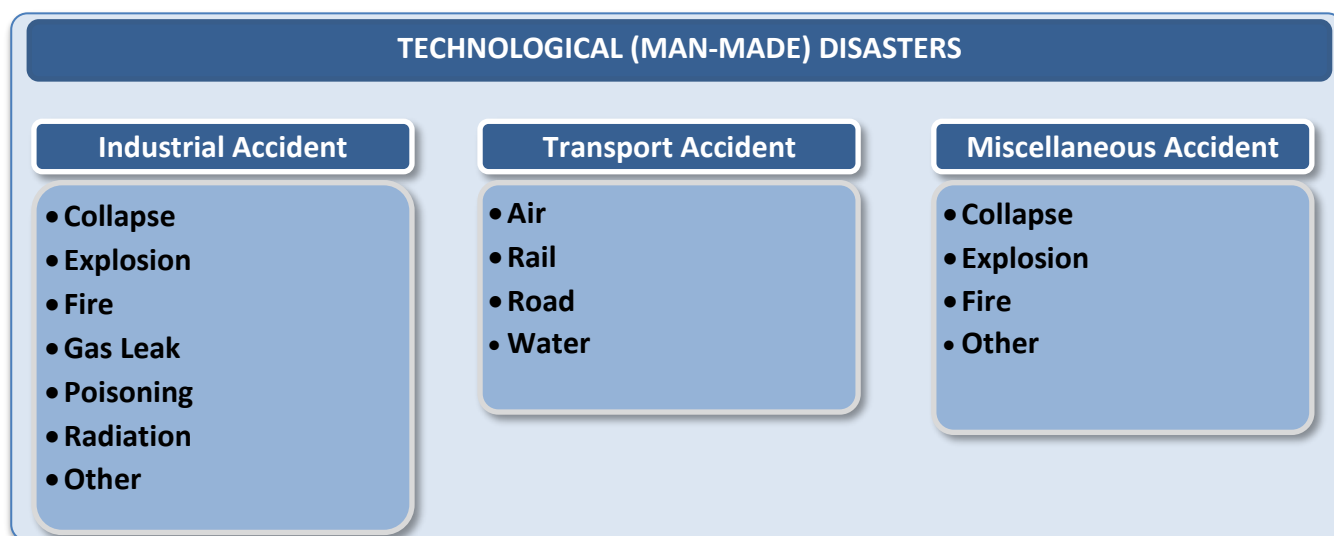


Figure 2.2: Technological (Man-made) disaster classification

Source: Adopted from Chan (2017)

Laframboise and Loko (2012) stated that the most reliable source of data on natural disasters is the Emergency Events Data Base (EM-DAT) maintained by the Collaborating Centre for Research on the Epidemiology of Disasters (CRED). Thus, the figures of disasters occurrence and impacts in this section will at most refer to EM-DAT. The CRED registers a “disaster” if at least one of the following has occurred: 10 or more fatalities, 100 or more people “affected,” a call for international assistance, or the declaration of a state of emergency (Few & Matthies, 2006; Laframboise & Loko, 2012). People “affected” by a disaster are defined as those injured, homeless/displaced, or requiring immediate assistance.

In recent years, the world has witnessed an increase in the intensity and frequency of natural disasters (EM-DAT, 2015). Evidence shows that there has been a long-term upward trend in the number of natural disasters since the latter part of the 20th century (Munich Re, 2007), which has

experienced over US\$ 170 billion events related to weather extremes such as windstorms, floods, droughts and heatwaves (Beniston & Stephenson, 2004). Large-scale disasters regularly affect societies across the globe, causing huge destruction and damage. Natural disasters can impose drastic consequences both directly and indirectly on people's lives and their livelihoods (Ingirige *et al.*, 2008). They added that disasters are considered as open windows of opportunity for creating communities that are more resilient. Therefore, the vulnerable societies are keen to adopt more mitigation measures to protect their lives and properties, which will lead to systematic improvement.

The world has witnessed an increasing number of disasters in last decades and these disasters have only happened within the last four decades (1970-2010). The natural disasters have caused more than 3.3 million deaths (or 82,500 a year) (Figure 2.3 shows cumulative deaths from disasters for 1970 to 2010), and 2.3 trillion dollars (1970-2008) in economic damages (WB, 2010), which is 0.23 percent of cumulative world output. This is due to the two geophysical hazards, 2010 Haiti earthquake and the 2004 Indonesian earthquake and tsunami have caused the highest death toll from natural disasters.

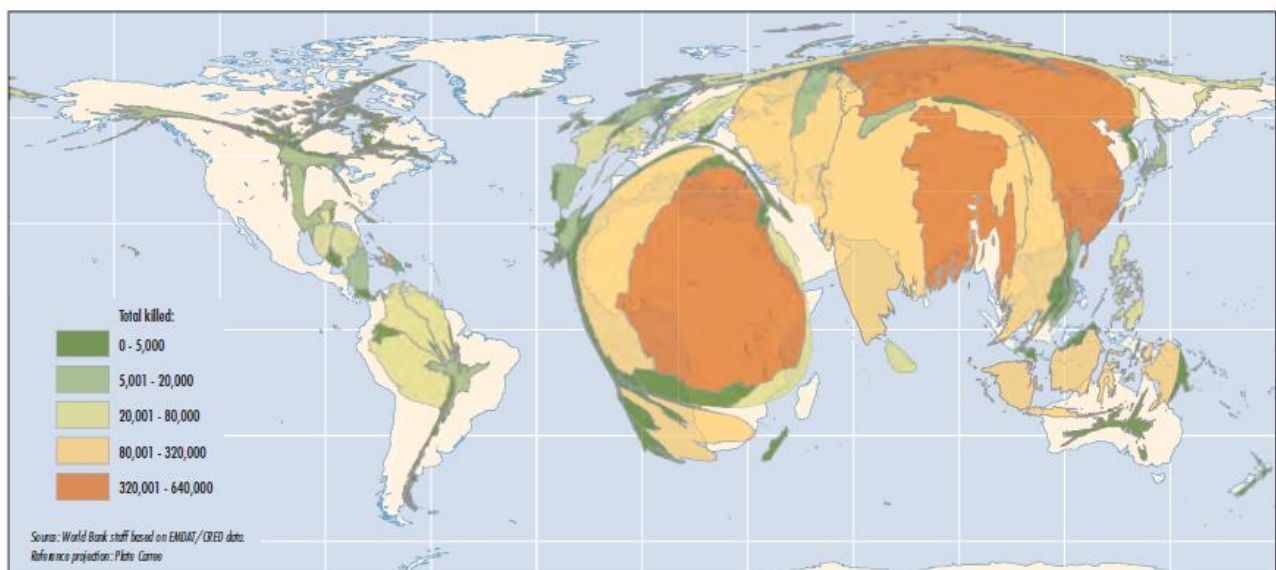


Figure 2.3: Cumulative deaths from disasters for 1970 to 2010

(Source: World Bank staff based on EM-DAT/CRED)

Natural disasters have resulted in significant economic and human loss in the millennia (Noy, 2009). From Figure 2.4, it can be seen that 2014 experienced 324 natural disasters, which was the third lowest number of reported disasters in the last decade, below the annual average disaster frequency observed from 2004 to 2013 were at 388. This is due to a smaller number of hydrological

and climatological disasters 20.3% and 34.4% below their 2014-2013 annual average, respectively (CRED, 2014). In the other hand, CRED (2013) reported that 2013 witnessed 330 triggered natural disasters. This was both less than the average of annual disaster frequency observed from 2003 to 2012 were at 388, and represented a decrease in associated human impacts of disasters which were, in 2013, at their level for 16 years, and this was mostly due to a smaller number of hydrological and climatological.

In terms of the number of people killed by disasters, Figure 2.4 shows that in 2014, deaths were 7,823 which was the lowest in the last 10 decades and much below the 2004-2013 annual average of 99,820 deaths. Whereas, 2013 recorded 21,610 deaths which also was very far from the 2003-2012 annual average of 106, 654 deaths. But big difference in deaths between 2014 and the average of 2004-2013, (see Figure 2.4). The big difference in deaths between 2013 and 2003-2012 mainly explained by the impact of the decade's average, of three years 2004, 2008 and 2010, with more than 200,000 people killed. Indian Ocean tsunami in 2004 recorded 226,408 deaths, the cyclone Nargis in Myanmar in 2008 recorded 138,366 deaths and the earthquake in Haiti in 2010 left 225,570 deaths (CRED, 2013, 2014).

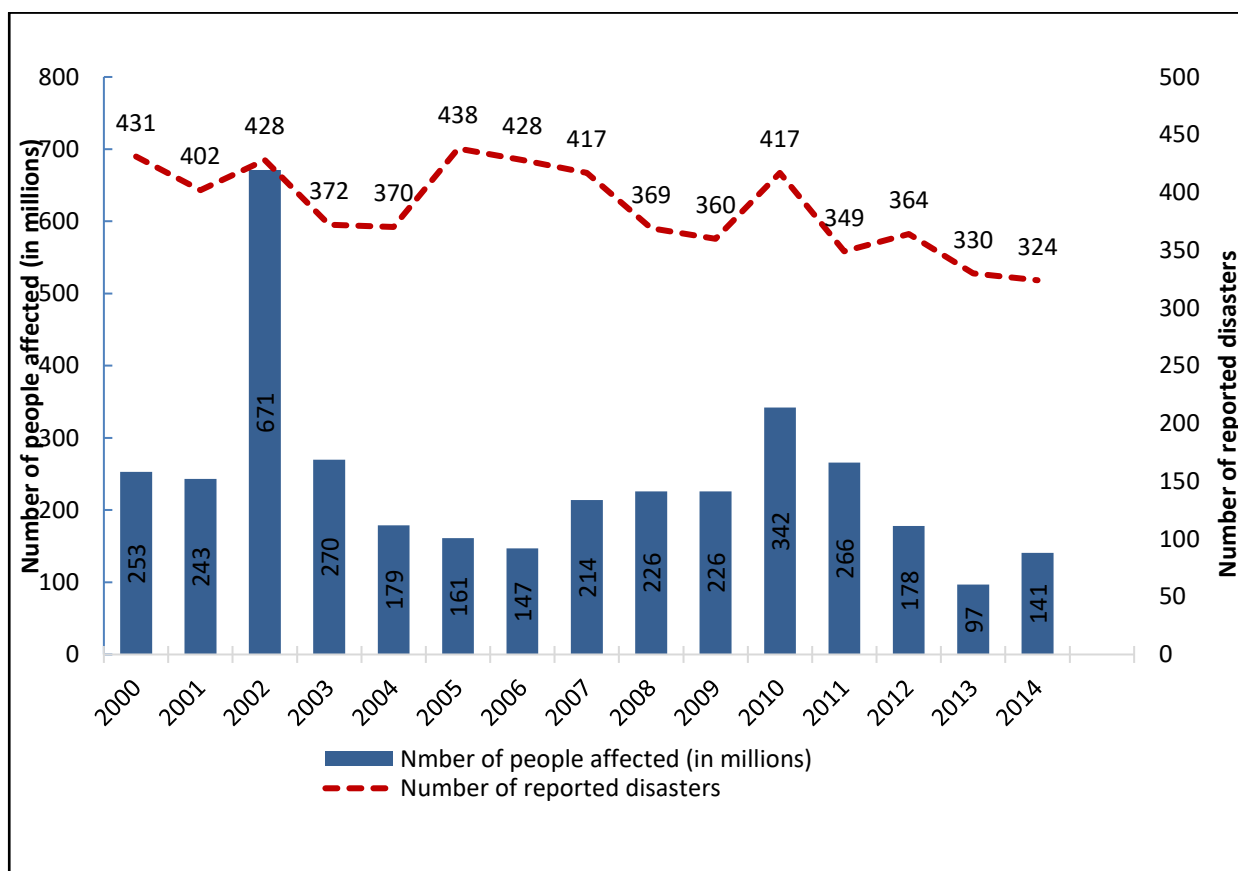


Figure 2.4: Trends in occurrence and affected people

(Source: EM-DAT, 2014)

UNISDR (2015) reported that economic losses from disasters such as earthquakes, tsunamis, cyclones and flooding are now reaching an average of US\$250 billion to US\$300 billion each year. Future losses are now estimated at US\$314 billion in the built environment alone. Therefore, it is crucial to adopt more mitigation measures to decrease these losses especially in the developing countries.

According to (CRED, 2013, 2014), over the last decade, China, the United States, Indonesia, the Philippines and India constitute together the top five countries that are most frequently hit by natural disasters. In 2013 and 2014, China experienced its highest number of natural disasters of the last decade. The country was affected by a variety of disaster types, including 32 floods and landslides, 30 storms, 15 earthquakes and one mass movement of geological origin, two droughts and one period of extreme temperature. On the other hand, the Philippines and Indonesia reported their second third lowest number of disasters in the last 10 years.

Natural disasters have a significant negative impact on real GDP, though this differs by type of disaster (Hochrainer, 2009). Moderate disasters can in fact have benefits on economic growth rates via the investment boost from reconstruction activities, but severe disasters never have positive growth effects (Fomby *et al.*, 2009; Loayza *et al.*, 2012; Peter *et al.*, 2012), which matches with (Ingirige *et al.*, 2008) who consider disasters as open windows of opportunity for creating communities that are more resilient. Therefore, the vulnerable societies are keen to adopt more mitigation measures in terms of their lives and properties and leading them to systemic improvement.

## **2.3 Floods**

Floods are considered a severe natural hazard and have had significant impacts on Man throughout history. They can destroy infrastructures, cause landslides, damage agricultural fields, and cause injury or death to both livestock and human kind (Norbiato *et al.*, 2008). The number of flood events has increased significantly all around the world over the last three decades (Parker *et al.*, 2007).

According to the U.S. National Weather Service, floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. As much as 90 percent of the damage related to all natural disasters (excluding drought) is caused by floods and associated debris flows (Dingman, 2009). They are the leading cause of natural disaster deaths worldwide and were responsible for 6.8 million deaths in the 20th century. Asia is the most flood-affected region,

accounting for nearly 50% of flood-related fatalities in the last quarter of the 20th century (Jonkman, 2005; Jonkman & Kelman, 2005; Noji, 2000).

Floods can be defined as a temporary covering of land by water outside its normal confines (Floodsite-Consortium, 2005; Munich Re, 1997; Schanze *et al.*, 2007). They happen in small and large river, in estuaries, at coasts and locally. Each flood event can be characterised by features such as water depth, flow velocity, matter fluxes, and temporal and spatial dynamics. Flooding in most cases is a natural phenomenon which in natural floodplains cannot be classified as a threat. Nevertheless, floods in intensively used catchments are often influenced by man through land use, river (Schanze *et al.*, 2007).

Flood events are natural disasters that naturally occur, and will keep occurring despite best efforts of governments and society to mitigate them. Flood refers to an excess accumulation of water across a land surface (Few & Matthies, 2006), which cannot normally be contained and hence cause inundation, or overflow of an excess of water that submerges land (Neussner, 2009), or not normally submerged (Few & Matthies, 2006), on usually dry land (Wilson, 2004), or not normally covered by water (Neussner, 2009; Tovey, 2008). In general, flood is too much of water in the wrong place, or presence of water in land that is usually dry. Many factors that contribute to flooding, of which, heavy rainfall of a long duration or high intensity, which create a high runoff in rivers or a build-up of surface water in areas of low relief (Arenas, 1983; Few *et al.*, 2004; Few & Matthies, 2006). Topography, soil condition, and ground water also are other factors that play important role in flooding. Intense rain from storms and cyclones may produce rapid runoff and sudden but severe flash floods across river valleys (Few & Matthies, 2006), or following a sudden release of water held by an ice or debris jam.

The main causes of changes in flood risk are climatic changes, changes in land use and other anthropogenic interventions, reducing soil infiltration and increasing runoff volumes (Green *et al.*, 2000), in addition to the amount of people and assets in flood-prone areas. The extensive flood risk is closely linked to the increased run-off caused by new urban development, a chronic under investment in citywide pluvial drainage, the location of informal settlements and social housing projects in low-lying flood prone areas and inadequate water management in the surrounding watersheds (ISDR, 2009b). There is also an argument that urbanization process leads to increased exposure of vulnerable people and assets in hazard prone places, which is also responsible for magnifying the hazards themselves, particularly floods. Therefore, flooding in urban areas is not just related to heavy rainfall and extreme climatic events; it is also related to changes in the built-up



areas themselves. Urbanization restricts where floodwaters can go by covering large parts of the ground with infrastructure, which obstruct the natural channels by constructing drains that force the water to move to rivers or streams more rapidly than it does in the natural conditions (Di Baldassarre *et al.*, 2010). Large-scale urbanization and population increases have led to large numbers of people, especially the poor, settling and living in flood plains in and around urban areas (Yuen & Kumssa, 2011). For instance, Soweto-on-Sea near Port Elizabeth in South Africa and Alexandra in Johannesburg, Miami and New York in USA, and Mumbai in India illustrate the argument of the settlement and living in the floodplains.

Flooding also depends on the hydrologic characteristics of the watershed in which rainfall accumulates. Steep topography increases the chance of flooding. Physical characteristics of the basin such as soil saturation and permeability, geography, slope, urbanization and vegetation further modulate the runoff potential (Davis, 2001), which matches with (ISDR, 2009b), (Di Baldassarre *et al.*, 2010) and (Yuen & Kumssa, 2011). Furthermore, there are some factors related to human being such as land use and diverting water drainage systems.

Floods affect more people worldwide than any other hazard. There are many different manifestations of flooding, including flash floods, coastal flooding, surface water and ponding floods (UNISDR, 2015). Number of flood events has increased significantly all around the world over the last three decades. While the number of fatalities per flood event exhibited an almost constant trend during the 1980s and 1990s, it has markedly decreased since the year 2000 despite the significant increase in the number of floods (Parker *et al.*, 2007), whereas, it has increased in the developing countries due to lack of preparedness and mitigation measures. For example, the Indian Ocean tsunami caused the highest death toll from floods (Gencer, 2013).

Floods have posed severe impacts at the human life and countries economic situation. According EM-DAT, 2495 floods occurred worldwide for the years 2000-2015 with 85,773 deaths, affected 1.4 billion people, and with a total damage of US\$403 Billion. Flash floods represent 382 events that caused 15,352 fatalities, 147 million affected people and total damages of US\$38.9 Billion. At more detailed level, in 2013, 33% of victims were from floods and the number of people killed by floods (9,819) which represents the highest of the decade with 45.5% of the global disaster mortality. Flooding in the south and east of Germany was the costliest natural disaster in 2013 with estimated economic of US\$ 12.9 billion (CRED, 2013).

Flood disasters still took the largest share in natural disasters occurrence in 2014 with 47.2%. They caused 42.3 million victims, or 30.0% of total disaster victims, and were responsible for 58.7% of the

total reported number of people killed and 37.7% of total damages (CRED, 2014). CRED added that 153 floods occurred in 2014, which were slightly below the number of floods occurred in 2013, but 20.3% below the 2004-2013 annual average on the one hand. On the other hand, the number of victims has dramatically decreased by 55.1% compared to decade's annual average. The flood which made the most important number of victims (15 million) occurred in China in June 2014. This decline in flood events and victims did not lead to minimize the damages, but increased to a rate of 19.4% (US\$37.4) above the decade's annual average (US\$31.3). The most expensive flood (US\$16 billion) occurred in the Jammu and Kashmir region in India (CRED, 2014). Floods also cause major losses in high-income countries, they contribute US\$104 billion to Average Annual Losses (AAL), which is equivalent to twice the public health expenditure in the Middle East and North Africa (UNISDR, 2015).

### **2.3.1 Flash floods**

One category of natural hazard, flash floods, rarely garners that level of attention. Yet according to the World Meteorological Organization (WMO), flash floods are the most lethal form of natural hazard (based upon the ratio of fatalities to people affected), and cause millions of dollars in property damage every year (WMO, 2007). This is, because flash floods tend to occur frequently but at a very small scale. Flash floods often impact poorer populations in remote locations. Individually they rarely capture news headlines, but cumulatively they can severely undermine a region's development (NOAA, 2010).

Flash flood is a "flood of short duration with a relatively high peak discharge" (Neussner, 2009), that follows the causative storm event in a short period (Georgakakos, 1992), heavy local rainfalls in mountainous area or in basins (Borga *et al.*, 2007), or strong flows occurring shortly after rainfall (Gruntfest & Huber, 1991), and are usually generated by extreme rainfall events associated with convective storms with relatively high rain intensities (Rozalis *et al.*, 2010). They are characterised by a quick rise of water levels causing a threat to the lives of those exposed with limited time to predict response (Norbiato *et al.*, 2008). It is also heavy or excessive rainfall in a short period of time that produce immediate runoff, creating flooding conditions within minutes or a few hours during or after the rainfall (CRED, 2014). The quick rise of water level within a short duration makes flash flood forecasting as the most difficult tasks in operational hydrology.

Flash floods are one of the most significant natural hazards in terms of the number of people affected and the number of fatalities. The potential for flash flood casualties and damage is increasing in many parts of the world due to the social and economic pressures on land use

(Abdelkhalek, 2011). Flash floods often induce landslides and debris flows leading to severe damage and casualties in local areas. Due to the complex process of flash flood formation, the complicated characteristics of river basins in mountainous and hilly areas and the uncertainty of short-duration heavy rainfalls, flash flood prevention is a worldwide problem posing a great challenge.

They differ from other kinds of floods in that they tend to develop in the same place and time of the rainstorm that caused them, which allows for short (minutes to a few hours) advance warnings issued but sometimes no alerts at all. Urbanization and population growth increase flash flood risk since there are far more people and infrastructures concentrated in flood prone zones. In addition, urban development creates conditions, such as impervious surfaces, conducive for rapid flood generation (Davis, 2001). The generation of flash floods is affected by complex factors which mainly include characteristics of the rain (intensity, duration, amount, and time-space distribution) and the physical and hydrological characteristics of watershed (area, length, slopes, shape, type of soil and land use, vegetation, antecedent conditions and others) (Rozalis *et al.*, 2010). Therefore, and due to the complexity of factors that affected generation of flash floods, the ability to predict them would be quite limited and depends on the many factors such as availability of rainfall information, its accuracy and spatiotemporal resolution, soil moisture estimation, surface parameters and the ability of hydrological models to represent the complex processes involved in flash flood generation (Yatheendradas *et al.*, 2008).

Recently, there is evidence to support the claim that due to global warming, extreme rainfall events are becoming increasingly frequent in the eastern Mediterranean region (Alpert *et al.*, 2002). Other evidence points to an increase in extreme rainfall events accompanied by a decrease in the total amount of rain (Alpert *et al.*, 2004). A possible consequence of this precipitation trend will be an increase in flash flood occurrence. Arid, semi-arid and Mediterranean regions are particularly vulnerable to such change due to water management issues, soil erosion and flash flood impacts (Alpert *et al.*, 2002).

Disaster risk is normally considered a function of the severity and frequency of the hazard, of the numbers of people and assets exposed to the hazard, and of their vulnerability or susceptibility to damage. The Global Risk Assessment report (GAR, 2015) on Disaster Risk Reduction has categorised flash floods as one of the more extensive risk layers, which are characterized by high-frequency but low-severity losses and are associated with localized and recurrent hazard events (UNISDR, 2015).

The main factors of the more intensive risk layer are the hazard and exposure that control the risk equation.

Flash floods are considered a severe natural hazard and have had significant impacts on Man throughout history. They can destroy infrastructures, cause landslides, damage agricultural fields, and cause injury or death to both livestock and human kind. Mediterranean areas are considered to have high flash flood potential (Norbiato *et al.*, 2008), and arid, semi-arid and Mediterranean areas in Egypt and Israel often suffer from flash floods. For example, in October 1997 a heavy rain storm caused flash floods and six deaths in Egypt; in December 1993 a flash flood in the Negev desert in southern Israel ended in loss of life and heavy damage to infrastructures (Rozalis *et al.*, 2010); and in October 2015 a torrential heavy rain accompanied strong winds in the Egyptian Mediterranean city of Alexandria caused flash floods ended in loss of life of seven people and massive economic losses (Angwin, 2015).

In terms of disaster mortality in 2014, the flash flood events occurred in Afghanistan in April and in Congo in October killing 431 and 154 people respectively. Both flash floods were classified of the top 10 natural disasters by number of deaths in 2014 (CRED, 2014). However, when looking at disaster mortality relatively to the number of inhabitants in the country, high mortality rates reported that flash floods in the Solomon Islands recoded (7.71/100,000) and Burundi (0.92/100,000) (CRED, 2014). According to the World Bank income classification, Solomon Islands and Burundi are classified as lower-middle income and low-income economies respectively, which emphasises that the lower-middle and low-income economies countries are exposed to flash floods more than other incomes.

The estimation of natural disaster damages in Africa remains extremely challenging as data are often poorly reported or lacking altogether. In 2014, damages were reported for two flash floods in Zimbabwe and the Democratic Republic of Congo, which equated to US\$20 million and US\$15 million respectively (CRED, 2014).

According EM-DAT, 2495 floods occurred worldwide for the years 2000-2015 left 85,773 deaths, affected 1.4 billion people, with total damage of \$403 Billion. Flash floods represent 382 events that caused 15,352 fatalities, 147 million displaced people with total damages of \$38.9 Billion.

### **2.3.2 Floods and flash floods in developed countries**

Floods and Flash flood are the most common disasters in developed countries, causing extensive damage, disruption, and loss in life. They are the most common natural disaster in the European

Region that has experienced in recent years some of the largest flood and flash flood events in its history. They caused extensive damage, loss of life and disruption (EM-DAT, 2015; WHO, 2013). WHO (2013) added that the effects of flash flooding on health are extensive and significant, ranging from mortality and injuries resulting from trauma and drowning to infectious diseases and mental health problems.

Europe has experienced a number of unusually long lasting rainfall events that produced severe floods and flash floods, (EM-DAT, 2015; Santato *et al.*, 2013), and several extreme floods and flash floods have occurred in Central European rivers. Rough cost estimates for the Elbe 2002 flood and flash flood alone are about \$3 billion in the Czech Republic and more than \$9 billion in Germany (Becker & Grünewald, 2003). 50 of the 53 countries in of the WHO European Region have experienced floods and flash floods during the past decade, with the most severe flash floods in Romania, the Russian Federation, Turkey and the United Kingdom (WHO, 2013). These flash floods have caused a death of 1000 persons and more than 3.4 million affected (Jakubicka *et al.*, 2010). A review of European data for the years 2000–2011 shows that the number of deaths from floods and flash flooding was highest in central Europe and the former Soviet Republics. Moreover, the frequency and intensity of floods and flash floods in Europe have clearly increased in the last few years, affecting millions (EEA, 2010) and causing an increase in economic losses (Barredo, 2009). Over the past ten years, Europe has experienced more than 165 major floods and flash floods. Flood and flash flood hazard increases for different reasons and several of them are correlated (Genovese, 2006) as a result from the confluence of both meteorological and hydrological factors, exacerbated by human actions (WMO, 2012). Therefore, the risk of these destructive floods and flash floods which posed a threat to human settlements across Europe throughout recorded history (Brázdil *et al.*, 2006; Macdonald, 2012) and has prompted hydrologists and engineers to develop tools for quantifying the risks such as flood and flash flood frequency analysis (Madsen *et al.*, 2014).

Flooding and flash flooding is Australia's most expensive natural hazard and 2010-2011 saw some of the biggest flood events in Australia's history. The federal government allocated 5.6 billion in recovery funding to Queensland alone, and almost \$1 billion to Victoria, primarily to restore public infrastructure (VAGO, 2013; Wenger, 2013). Climate change scenarios predict an increase in intensity and frequency of floods, potentially exposing Australia to even greater damages in the future. Flood management is thus a key area for improving adaptive capacity (Wenger, 2014). The current flood management in Australia is 'resilience' and through federal leadership and funding, it attempts to promote shared responsibility for disasters. In addition, Victoria has experienced some

of the most extensive and damaging floods in its history (2010-2013), which affected 70 of the 79 Victorian local government areas, with 16 very severely impacted, moreover, the total estimated cost for relief and recovery was \$971 million (VAGO, 2013). Perhaps the most significant aspect of Australia's resilience approach is the greater availability of flood risk information. Whereas, the cost of the Solomon Islands flash flood in 2014 amounted to US\$ 24 million, which is very below the US\$ 1.32 billion 2004-2013 annual average.

North America has experienced locally severe economic damage, plus substantial ecosystem, social and cultural disruption from recent weather-related extremes, including floods (IPCC, 2014). Floods hazards produce risk as they interact with increases in exposed populations, infrastructure, and other assets and with the dynamics of such factors shaping vulnerability as wealth, population size and structure, and poverty. Over the past several decades, economic damage from severe weather has increased dramatically, due largely to increased value of the infrastructure at risk. Annual costs to North America have now reached tens of billions of dollars in damaged property and economic productivity, as well as lives disrupted and lost (Field *et al.*, 2007).

Floods and flash flood-related disasters, such as landslides, are a traditional and serious risk in Japan. In the 1940s and 50s, flood disasters took thousands of lives. In recent years, Japan has witnessed a significant increase in precipitation levels and in the frequency of extreme climatic events such as typhoons, which have raised the likelihood of flash flood disasters. Meanwhile, increasing concentration of people and economic assets has led to an escalation of financial costs of disasters.

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### **2.3.3 Floods and flash floods in developing countries**

Poor communities (developing countries) often live in the most hazardous and unhealthy environments in urban areas. Many build their homes and grow their food on river flood plains in towns and cities. Others construct their shelters on steep, unstable hillsides, or along the foreshore on former mangrove swamps or tidal flats. People suffering these poor conditions may find their problems compounded by the consequences of climate change (Yuen & Kumssa, 2011). During the last decades, many developing regions have been affected by the occurrence of severe hydrogeological events, such as flash floods, causing thousands of fatalities and dramatic economic damages (EM-DAT, 2013).

Many of Asian countries were impacted by floods that left severe damaged in economic and losses in human lives. In the Asian region, millions of people's lives are affected yearly by natural hazards such as flooding, typhoons and droughts. In the recent years, a number of natural hazards has struck the Asian region; of all the huge disasters that claimed the lives of thousands the Indian Ocean tsunami in 2004 was the largest, estimated to have killed more than 230,000 people (Falk, 2015). The 2010 Pakistan floods directly affected an estimated 14-20 million people, 1,700-2,000 people died and the total economic impact was US\$ 40 billion (Keoduangsine & Goodwin, 2012). Nearly 1.1 million homes were damaged or destroyed, and at least 436 health care facilities were destroyed. The flooding lasted almost six months in some areas and caused US\$ 9.7 billion in damages in forty-six of the country's 135 districts (Kirsch *et al.*, 2012). 80% of the damaged or destroyed homes were of mud brick walls that exposed them to flood risk. In 2010 floods affected the LMRB countries (Cambodia, Laos, Thailand and Vietnam), and destroyed more than 64 million hectares of rice paddy, affected 1.1 million households, about 5 million people, and it was estimated that the total damage to property was US\$ 1.2 billion (Keoduangsine & Goodwin, 2012; MRC, 2010). In 2012, the Philippines suffered heavy floods caused by typhoon Bopha, in this event 1020 people were confirmed dead, 844 people were missing, 1.2 million families were affected and total damages estimated at US\$ 1 billion (Keoduangsine *et al.*, 2014).

Many of the urban poor in Africa face growing problems of severe flooding (Douglas *et al.*, 2008). This is due to the increase of storm frequency and intensity related to climate change. Moreover; the vulnerability to floods has increased in Africa during the recent decades (Di Baldassarre *et al.*, 2010; Douglas *et al.*, 2008), and this due to lack of preparedness measures such as warning system, and needed resources to avoid or mitigate floods effects. Heavy rains and cyclones in 2000 in

Mozambique led to the worst flooding in 50 years. Upwards of one million people were directly affected.

The rains over Indian Oceans in 2002 created major disasters in East African, for instance, floods and mudslides forced tens of thousands of people to leave their homes in Rwanda, Kenya, Burundi, Tanzania and Uganda and killed more than 112 people in East Africa (Douglas *et al.*, 2008). In August 2006, Addis Ababa floods killed more than 100 people and destroyed homes in eastern Ethiopia after heavy rains caused a river to overflow. The overflowing Dechatu river hit Dire Dawa town at night drowning 129 people and wiping out 220 homes (ActionAid, 2006). Torrential rains and flooding affected 600,000 people in 16 West African nations in September 2009 (Baldassarre *et al.*, 2010). The worst hit countries were Burkina Faso, Senegal, Ghana and Niger. This event followed by 2007 floods that displaced more than a million people in Uganda, Ethiopia, Sudan, Burkina Faso, Togo, Mali and Niger, and claimed over 500 lives and the 2008 flooding in Mozambique (United Nations, 2009). These events, and the continually increasing number of people affected by flooding during the 2009–2010 rainy season, which numbered about 25,000 through April 20, are the most recent examples of the growing flood risk in Africa (Baldassarre *et al.*, 2010). Flash floods in 2013, in Kenya claimed the lives of 96 people and caused the displacement of 140,000 people (Hoedjes *et al.*, 2014). Flood appears to be a serious threat to African countries, and modelling the effects of possible future of floods shows that the pattern of rare large floods is going to change much more than long-term average river flows. General literature concluded by (Baldassarre *et al.*, 2010; Douglas *et al.*, 2008; United Nations, 2009) recognizes that flood and flash flood warning systems are necessary for people living on floodplains.

According to WB (2014) floods represent one of the serious challenges to growth and stability in the Middle East and North Africa (MENA). Over the last 30 years (1981–2011), floods have been the most recurring disasters recorded in EM-DAT, with at least 300 events (53 percent of the total number of disasters), indicating a strong need for early warning systems. The increase in disasters in the MENA region is related to increasing in vulnerability and exposure. The 2011 Global Assessment Report on Disaster Risk Reduction found that although global flood mortality risk has been on the decrease since 2000, whereas, in MENA, it is still increasing (UNISDR, 2011). The number of flash floods and people affected or killed has doubled during the last 10 years (WB, 2014). For example, flash floods of Bab-El-Oued in the Algerian capital, which left more than 900 casualties in 2001; or the flash floods that hit Jeddah, Saudi Arabia, in 2009, 2010, and 2011, which were registered as the worst floods in 30 years. Flooding is also a major risk for urban areas. It is often



caused by buildings, infrastructure, and paved areas that prevent infiltration and is exacerbated by overwhelmed drainage systems. The flood that hit Sana'a, Republic of Yemen, in May 2010, is an example. Flooding occurred in low-lying residential areas with inadequate drainage systems, affecting hundreds of homes and killing 8 people (WB, 2014). Therefore, this pattern further demonstrates the need for comprehensive approaches to urban development and water resource management, besides the MENA's rapid urbanisation, which is increasing the exposure of people and economic assets to disaster events. Table 2.3, Table 2.4, Table 2.5 show a summary of loss of lives and property damages due to flood in 2000-2015 for all the continents, developing countries and developed countries.

During 2000-2016, 2750 flood disasters occurred, and almost distributed among world's continents. Asia has recorded the highest rate at 40.0%, followed by Africa and America, Europe at 23.6%, 20.4% and 13.4% respectively, whilst Oceania share was the lowest at 2.6% (see Table 2.3). Flood disasters were mainly concentrated in China, India, and Indonesia which recorded 426 flood disasters out of 1100 flood disasters in Asia (see Table 2.4).

Table 2.3: Summary of deaths and damages due floods 2000-2016

Continent	Occurrence	%	Total deaths	%	Total affected	%	Total damage ('000 US\$)	%
Africa	648	23.6%	12936	14.0%	44999700	3.1%	5873675	1.3%
Americas	562	20.4%	12132	13.2%	45457307	3.1%	72220815	15.8%
Asia	1100	40.0%	65181	70.7%	1362387902	93.3%	271323166	59.2%
Europe	368	13.4%	1734	1.9%	6598577	0.5%	95198967	20.8%
Oceania	72	2.6%	208	0.2%	754975	0.1%	13454247	2.9%
Total	2750	100%	92191	100%	1460198461	100%	458070870	100%

(Source: Adopted from EM-DAT, 2014)

Table 2.4: Deaths and damages due floods 2000-2016 for developing countries

Country Name	Occurrence	Total Deaths	Total Affected	Total Damage ('000 \$)
India	148	23452	294939535	42294347
China P Rep	173	11078	829598958	130938474
Pakistan	57	6584	46001293	18707148
Indonesia	105	3546	4691512	5853633
Haiti	34	3089	607278	1000
Bangladesh	32	2764	72706135	3014000
Viet Nam	55	2544	16251362	3088502
Brazil	62	2416	7265282	5097870
Afghanistan	62	2237	438244	23000
Thailand	43	2216	36100425	41895067
<b>Total</b>	<b>771</b>	<b>59926</b>	<b>1308600024</b>	<b>250913041</b>

(Source: Adopted from EM-DAT, 2014)

The human impact, measured in terms of number of deaths, was essentially concentrated in Asia with percent of 70.7%, whereas, the rest were distributed between Africa, America, Europe and Oceania with shares of 14.0%, 13.2%, 1.9% and 0.2% respectively. India and China have registered 34,530 deaths which contributed to 53% of the total deaths in Asia. In terms of floods impacts, the total number of deaths in the top ten developed countries is less than number of deaths in Bangladesh; top ten developed countries registered 2653 deaths whilst Bangladesh registered 2764 deaths (see Table 2.4 and Table 2.5).

Table 2.5: Deaths and damages due floods 2000-2016 for developed countries

Country Name	Occurrence	Total Deaths	Total Affected	Total Damage ('000 \$)
Russia	43	552	1057120	3293470
Mexico	31	513	3405124	3019600
United States	81	505	11858247	42204330
Turkey	22	246	167455	932000
Venezuela	18	218	289227	333000
Japan	16	192	565408	12197000
Italy	27	151	77193	12350000
France	26	115	61998	7204350
Bulgaria	18	82	59817	855200
Australia	30	79	237608	12589500
<b>Total</b>	<b>312</b>	<b>2653</b>	<b>17779197</b>	<b>94978450</b>

(Source: Adopted from EM-DAT, 2014)

The total affected people by floods were almost entirely concentrated in Asia by 93.3% (1.36 billion) of total number of affected people, China and India have contributed by 1.12 Billion due to the high number of floods. The total affected in the developed countries were very small compared to the developing countries, Vietnam has recorded about 16.25 million as shown in Table 2.4, which is little less than the total of top ten developed countries at 17 million (see Table 2.5).

Most damages from floods were distributed between Asia at 59.2%; damages in China and India exceeded US\$ 173 billion; Europe 20.8%, America 15.8%, Oceania 2.9%, and Africa 1.3%. United States recorded the highest number of total damages in the top ten developed countries with US\$ 42 billion, whereas China recorded the highest in the developing countries with US\$ 131 billion.

Table 2.4, Table 2.5 and their analytical procedure show that there are big differences between developed and developing countries in terms of floods and their impacts. These differences are related to absence of a comprehensive flood risk mitigation plans in the developing countries. These plans are usually composed of a series of measures implemented in the catchment scale that ensure a limitation of flood hazard and exposure (EM-DAT, 2015).

Researcher such as Brandimarte *et al.* (2009) suggested the implementation of several non-structural measures, among which the most important are: strengthening of hydrometric gauging network (early warning systems), risk awareness campaign for the population living in the flood-prone areas, delineation of flood-prone areas for limiting urban expansion, and promotion of reforestation programme. In addition, the developing countries are commonly characterised by a lack of hydrological and topographical data (prevents practitioner from reliable estimation of potential flood events) to support the design of flood risk mitigation and management plans, as well as the planning of reliable structural and non-structural measures (Yan *et al.*, 2013). However, the low-income countries lack the provision of these abilities and established data centres to support establishment of flood risk mitigation measures such as early warning systems.

#### **2.3.4 Floods and flash floods in Jordan**

In the arid and semi-arid regions, such as Jordan, water resources are limited due to severe and increasing demand due to expanding populations, increasing per capita water use and irrigation. Floods are infrequent, but extremely damaging, and threatening lives and infrastructure due to urban development. Ecosystems and archaeological places, such as Petra, are fragile, besides the threat from groundwater abstraction and the management of surface flows. Added to these pressures is the uncertain threat of climate change (Wheater *et al.*, 2008). Therefore, effective water management is essential and requires appropriate decision support systems, including modelling tools.

Jordan is exposed to diverse natural hazards and disaster risks. Key amongst them includes earthquakes, droughts, floods and desertification. Climatic hazards pose a set of threats to Jordanian economic and human development, particularly the droughts and flash flooding. In particular, parts of the country face severe localized flash flooding; e.g. Petra, Aqaba, Ma'an and the various wadis. Flash flooding has historically caused damages to local tourist infrastructure, archaeological sites and urban infrastructures (UNDP, 2011). Incidents of flash flooding in Jordan have claimed the lives of a few hundred in Jordan over years and affected the lives and livelihoods of thousands, in the past half century floods have taken of 345 persons and affected 24,321 lives. Additionally, floods usually leave vast agricultural areas covered with heavy water (UNDP, 2008, 2009).

The National Disaster Response Master Plan (NDRMP) of Jordan (2004) identifies flash floods as one of the main potential hazards and threats to Jordan. According to Seibert (2009), it is evident that floods are one of the dominant sources of hazard to the country.

Flash Flooding hazard is affecting Jordan and represents that most significant problem affecting the tourism area (Petra, Aqaba) which cause a significant impact in the economic and social life for area residents. The Flash floods have become severe in recent years due to the deforestation in the upstream, the steep slopes of the Wadis with the new construction. Between the periods of 1963-2014, more than twenty major floods have occurred in the region.

Historic records and rainfall-runoff data in southern Jordan indicate that large floods occurred frequently in the past century (Al-Qudah, 2011). As late as 1940, a “terrific rain- and hail-storm” literally washed away half of modern Aqaba (Schick, 1971, cited in Al-Qudah, 2011). The decade preceding the instrumental period, which started in 1950-1951, witnessed at least three major floods in southern Jordan; on January 7, 1944, in 1945 and a major flood on May 12, 1950. In March 1966, a catastrophic flood struck the town of Ma’an in southern Jordan. It is reported that approximately 200 people were killed and over 250 were wounded. About half of the buildings of the town were destroyed and over three thousand people were rendered homeless (Newspaper, 1966, cited in Al-Qudah, 2011). The estimated flow of this flood reached a peak discharge of 540 m<sup>3</sup>/sec (CWA, 1966). Schick (1971) mentioned in his study of Ma’an flood, that in fact, a flood may be expected almost every year in southern Jordan based on observations of residents.

Jordan witnessed many floods in 2014, which caused massive losses in lives and properties. In May of 2014, several regions in the Kingdom witnessed heavy rain that caused floods as the country was affected by unstable weather conditions, the Petra region roads were closed due to intensity of floods, a family in Ma’an was rescued by helicopter, and students were unable to go to their schools due to flood (Freij, 2014). In November 2014, at least three people died in flooding affecting the north west of the Jordan country, and 54 people were injured in separate incidents after they were trapped by floodwater in different areas in Jordan (Richard, 2014). November 2015 witnessed a heavy rain storm of that lasted about 40 minutes, which flooded the streets in Amman-Jordan that has led to four deaths, and high cost damages estimated by US\$ 7 million, water level reached more than 2.5 m in streets tunnels, and about 80 cm in the main roads (Noghay, 2015). Therefore, Jordan needs to adopt a comprehensive national strategic plan to reduce the flood effects, which considered as the first hazard threatening the country.

#### **2.3.4.1 Flooding and flash flooding in case study area**

According to Jordan Tourism Board (JTB), Petra as a tourist city, contributes (direct and indirect) \$3.41 billion into the Jordanian economy (JTB, 2011). The pressure of tourism upon Petra and Wadi Musa will increase in the coming years, since the authorities plan to transform the region from a

“Tourist Attraction” to a “World Class Tourist Destination”. This will also increase pressure upon the natural resources of the region and would thus exacerbate the risks of disasters. At the same time, there will be more tourists exposed to experiencing hazards; e.g. flash flooding. Therefore, it is crucial to study this area and determine the most dangerous hazard threatening it.

Flash floods historically posed major and serious threat to Petra Region and the tourist and local activities in Petra as well as to the monuments themselves. As a result of this, hydrologists ranked it as the wadi with the highest risk in Jordan (Al-Weshah & El-Khoury, 2001). Geologic investigations on the wadi beds reveal that Petra is considered as an ephemeral wadi with intermittent flash floods of flows that can exceed the 298 m<sup>3</sup>/s threshold (Al-Weshah & El-Khoury, 2001). However, the floods in the area do not occur every year. Nevertheless, at certain years the extent of flood can be huge (2.42m<sup>3</sup>/sec was recorded as maximum mean daily discharge during 1963). Its floods may be hydraulically categorized as a hybrid of debris and turbid flows.

As documented in most of the available studies, the flood that occurred in April, 1963 was an extreme event, probably with a 100-year return period, eyewitnesses stated that the height of the floodwater was about 10 metres, despite the great emergency efforts, twenty French tourists lost their lives (Al-Weshah & El-Khoury, 1999). Therefore, floods and flash floods have historically caused a major threat to the Wadi Mousa City. Due to this, hydrologists ranked it as the wadi- it is a drainage course that is formed by water, but is distinguished from river valley or gully in that surface water is intermittent or ephemeral- with the highest risk/damage in Jordan. Moreover, floods and flash floods are still causing major threats to the Petra Region, flash flood occurred at the end of January 2013 has left damages in infrastructure, private and public properties that exceeded \$10 million.

Many centuries ago, Nabataeans (the Arabian people who build Petra city at the first century BCE) had designed an integrated network of hydrological systems throughout the area of Petra. This system protected the city from the recurrent threat of flash floods. Over the years, this system has degenerated due to lack of maintenance. Downstream, the large flow can endanger the population of the Wadi Mousa and the visiting tourists. Historical records concerning flash floods threatening Petra, south Jordan, have shown that flood protection and mitigation measures are urgently needed to protect tourists and the existing monuments (Al-Weshah & El-Khoury, 1999). One of these measures is establishing a local mechanism that helps make pro-active climate information available to support better preparedness and resilient planning (Hoedjes *et al.*, 2014). Therefore, the mechanism that might contribute to flood prevention and mitigation is the early warning system, which also helps make pro-active information about incoming floods.

Local authorities have adopted many mitigation measures trying to prevent flooding in Petra Region. Most of these measures are construal measures, whereas non-construal measures are non-existent to some extent. These measures will be investigated through the semi-structured interviews that researcher intends to conduct in the data collection stage. In this context, flash flood early warning system guidance (FFEWSG); if implemented in the study area that, will help to reduce flash flood impacts. Moreover, it could be used as a good practice for Jordan and the world to benefit from such guidance and adopt it into their mitigation systems to reduce the disruption and economic losses resulting from flash flooding.

## 2.4 Disaster Risk Management

According to ISDR (2009a) Disaster Risk Management (DRM) is defined as “The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster”. DRM, as shown in Figure 2.5, can be broken down into three stages: pre-disaster stage, emergency/disaster stage, and post-disaster stage. DRM traditionally follows four phases: mitigation/prevention and preparedness in the pre-disaster stage, response in the emergency stage, and recovery/reconstruction/recovery in the post-disaster stage (ADRC, 2005; Moore *et al.*, 2015; Tingsanchali, 2012). Each phase has particular needs, requires distinct tools, strategies, and resources and faces different challenges. The phases addressed below relate to the resiliency and recovery of the local community, properties and economy before and after a major disaster (IEDC, 2016).

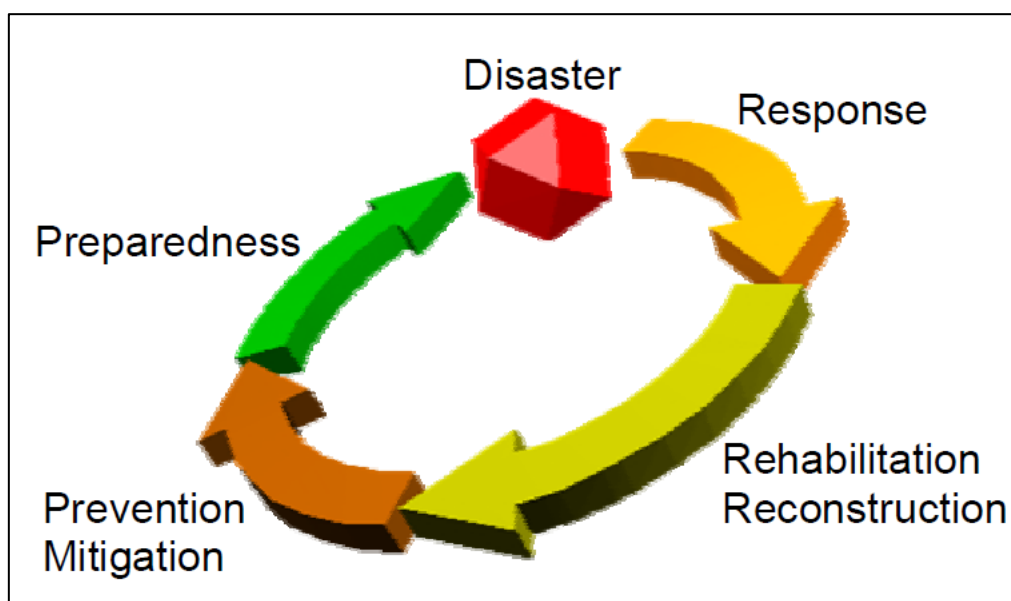


Figure 2.5: Disaster Risk Management Cycle

- **Prevention/Mitigation**

Prevention/ mitigation is defined as sustained action to reduce or eliminate risk to people and property from hazards (disasters) and their effects. It looks at long-term solutions to reduce risk as opposed to preparedness of hazards. Disaster mitigation includes those activities designed to prevent or reduce losses from disaster. It is usually considered the initial phase of emergency management, although it may be a component in the other phases (Sena & Michael, 2006, p. 130). In "*Prevention/Mitigation*" phase, efforts are made to reduce vulnerability to disaster impacts such as injuries and loss of life and property, and prevent or mitigate damage (*e.g.* construction of dikes and dams against floods) (ADRC, 2005). This might require modifications in building codes to reduce losses from dam and levees to prevent flooding, revised zoning and land use planning to limit or prevent development in floodplains, strengthening of public infrastructure, and other efforts to make the community more resilient to a catastrophic event (IEDC, 2016; Sena & Michael, 2006). Sena and Michael (2006) argue that the goal of mitigation is to create economically secure, socially stable, better built, and more environmentally sound communities that are out of harm's ways. The following widely accepted tools are used to reduce risks: (i) Hazard identification and mapping, (ii) Design and construction applications (iii) Land-use planning (iv) Financial incentives (v) Insurance (vi) Structural controls.

- **Preparedness**

Disaster preparedness is defined as a state of readiness to respond to a disaster. More broadly it is stated as the leadership, training, readiness and exercise support, and technical and financial assistance to strengthen citizens, communities, state, local governments professional emergency workers as they prepare for disaster, mitigate the effects of disaster, respond to community needs after a disaster, and launch effective recovery efforts (Sena & Michael, 2006, p. 114).

Activities and measures for ensuring an effective response to the impact of hazards are classified as "*Preparedness*" phase (*e.g.* emergency drills and public awareness) and are not aimed at averting the occurrence of a disaster (ADRC, 2005). Preparedness focuses on understanding how a disaster might impact the community and how education, outreach and training can build capacity to respond to and recover from a disaster. This may include engaging the business community, pre-disaster strategic planning, and other logistical readiness activities. The disaster preparedness activities guide provides more information on how to better prepare an organization and the business community for a disaster (IEDC, 2016). Preparedness includes designing warning systems, planning for evacuation, and reallocation, storing food and water, building temporary shelters,

devising management strategies, and holding disaster drills and exercises. Contingency planning is also included in preparedness as well as planning for post-impact response and recovery (Sena & Michael, 2006). Sena and Michael added that preparedness consists of three basic steps: preparing a plan, training to the plan, and exercising the plan. Preparedness deals with the functional aspects of emergency management such as the response to and recovery from a disaster, whereas mitigation attempts to lessen these effects through pre-disaster actions as simple as striving to create “disaster-resistant” communities.

- **Response**

Response is the immediate reaction to disaster (Sena & Michael, 2006). It may occur as the disaster is anticipated, as well as soon after it begins. “*Response*” phase includes such activities as rescue efforts, first aid, firefighting, first aid treatment, monitoring of secondary disaster, construction of temporary housing, Establishment of tent villages and evacuation (ADRC, 2005). Response addresses immediate threats presented by the disaster, including saving lives, meeting humanitarian needs (food, shelter, clothing, public health and safety), clean-up, damage assessment, and the start of resource distribution. As the response period progresses, focus shifts from dealing with immediate emergency issues to conducting repairs, restoring utilities, establishing operations for public services (including permitting), and finishing the clean-up process (IEDC, 2016).

- **Rehabilitation/Reconstruction/Recovery**

“*Rehabilitation/Reconstruction/Recovery*” the fourth phase of disaster, considerations of disaster risk reduction should form the foundations for all activities (ADRC, 2005). It is the restoration of all aspects of the disaster’s impact on a community and the return of the local economy to some sense of normalcy. By this time, the impacted region has achieved a degree of physical, environmental, economic and social stability (IEDC, 2016). The primary aim of recovery is to assist the affected community to regain a proper level of functioning following a disaster both initially and in the long term. It is “the coordinated process of supporting emergency-affected communities in reconstruction of the physical infrastructure and restoration of emotional, social, and physical wellbeing” (Sena & Michael, 2006, p. 125).

The recovery phase of disaster can be broken into two periods. The short-term phase typically lasts from six months to at least one year and involves delivering immediate services to affected communities and parties. The long-term phase, which can range up to decades, requires thoughtful strategic planning and action to address more serious or permanent impacts of a disaster.



Communities must access and deploy a range of public and private resources to enable long-term economic recovery (IEDC, 2016). Table 2.6 shows some examples of measures in each phase. Taking appropriate measures based on the concept of disaster risk management in each phase of the disaster risk management cycle can reduce the overall disaster risk (ADRC, 2005).

Disaster Risk Reduction (DRR) describes the development and application of policies, strategies and practices that minimise vulnerabilities and disaster risks throughout a society, to avoid (prevent) or to limit (mitigate and adapt to) the adverse impacts of hazards, within the broad context of sustainable development (Baas *et al.*, 2008; Davies *et al.*, 2008; ISDR, 2004).

Table 2.6: Example of Measures in Each Disaster Risk Management Phase

Disaster Phase	Flood	Storm (cyclone, typhoon, hurricane)
Prevention Mitigation	<ul style="list-style-type: none"> <li>- Construction of dike</li> <li>- Building of dam</li> <li>- Forestation</li> <li>- Construction of flood control basins/ reservoirs</li> </ul>	<ul style="list-style-type: none"> <li>- Construction of tide wall</li> <li>- Establishment of forests to protect against storms</li> </ul>
Preparedness	<ul style="list-style-type: none"> <li>- Construction and operation of meteorological observation systems</li> </ul>	<ul style="list-style-type: none"> <li>- Construction of shelter</li> <li>- Construction and operation of meteorological observation systems</li> </ul>
	<ul style="list-style-type: none"> <li>- Preparation of hazard maps</li> <li>- Food &amp; material stockpiling</li> <li>- Emergency drills</li> <li>- Construction of early warning systems</li> <li>- Preparation of emergency kits</li> </ul>	
Response	<ul style="list-style-type: none"> <li>- Rescue efforts</li> <li>- First aid treatment</li> <li>- Fire fighting</li> <li>- Monitoring of secondary disaster</li> <li>- Construction of temporary housing</li> <li>- Establishment of tent villages</li> </ul>	
Rehabilitation/ Reconstruction	<ul style="list-style-type: none"> <li>- Disaster resistant reconstruction</li> <li>- Appropriate land use planning</li> <li>- Livelihood support</li> <li>- Industrial rehabilitation planning</li> </ul>	

(Adopted from ADRC, 2005)

Both the internationally agreed Hyogo Framework for Action on Disaster Risk Reduction and Disaster Management (“the Hyogo Framework”) and the Pacific Islands Disaster Risk Reduction and Disaster Management Framework for Action (2005 – 2015) (“the Madang Framework”) outline a broad-based vision of DRR, encompassing governance, risk assessment and early warning, knowledge and education, underlying risk factors in the context of development and disaster preparedness and response (UNISDR & UNDP, 2012). In March 2015, UN member states adopted the successor to HFA, the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030. The SFDRR recognises the cross-cutting nature of DRR policy and calls on stakeholders to help governments (Calkins, 2015). It also assigned four priorities for action:

Priority 1: Understanding disaster risk.

Priority 2: Strengthening disaster risk governance to manage disaster risk.

Priority 3: Investing in disaster risk reduction for resilience.

Priority 4: Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.

In their approach to disaster risk reduction, states, regional and international organizations and other relevant stakeholders should take into consideration the key activities listed under each of these four priorities and should implement them, as appropriate, taking into consideration respective capacities and capabilities, in line with national laws and regulations (UNISDR, 2005).

#### **2.4.1 Flood risk management**

The probability of the occurrence of potentially damaging flood events is called flood hazard (Schanze *et al.*, 2007). Potentially damaging means that there are elements exposed to floods which could, but need not necessarily, be harmed (Floodsite-Consortium, 2005). Damage by flood hazards depends on the vulnerability of exposed elements (Schanze *et al.*, 2007). These three terms will be discussed in details later in this section.

Flood risk emerges from the convolution of flood hazard and flood vulnerability (ISDR, 2004). It can be defined as the probability of negative consequences due to floods and depends on the exposure of elements at risk to a flood hazard (Schanze *et al.*, 2007). To describe flood risk, the conceptual Source-Pathway-Receptor-Consequence-Model is proposed (ICE, 2001). Figure 2.6 shows a simple causal chain ranging from the meteorological and hydrological events either inland or at coasts through the discharge and inundation (pathways) and the physical impacts on elements at risk (receptors) to the assessment of effects (consequences).

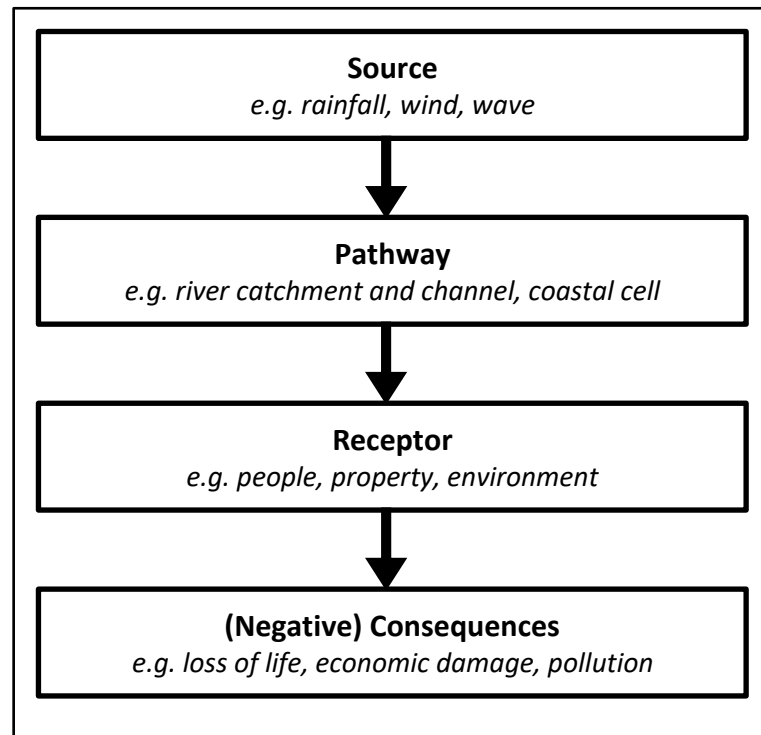


Figure 2.6: Source-Pathway-Receptor-Consequence-Model

Source: (ICE, 2001, P. 3)

**Flood risk management (FRM)** is “an approach dealing with flood risk based on the notion that risks cannot be taken away entirely but only partially and always at the expense of other societal goals” (Klijn, 2009), or the “continuous and holistic societal analysis, assessment and mitigation of flood risk” (Schanze, 2006). Management is interpreted, therefore, as decisions and actions undertaken to analyse, assess and (to try to) reduce flood risks (Schanze *et al.*, 2007). In this case, FRM covers risk analysis, risk assessment, and risk reduction (Hall *et al.*, 2003; Plate, 2002; Sayers *et al.*, 2013).

Flood management is increasingly discussed as a risk management process, encapsulating as this does, terms such as ‘resilience’, ‘vulnerability’, ‘hazard’ and ‘uncertainty’ (De Bruijn *et al.*, 2007). Flood management is increasing in complexity, but it is equally evident that flood research has undergone a similar process. This complexity is in part explained by the accumulation of competing understandings (Brian, 2010).

FRM aims to reduce the consequences of floods, preventing losses and damages by preventing flooding and/or by preventing the exposure of people and property to flooding, in general it aims at reducing the flood hazard, i.e. the probability of flooding. Attempts to decrease vulnerability, i.e. the other aspect of risk that have been of minor importance (Klijn, 2009; Vis *et al.*, 2003). FRM requires the holistic development of a long-term strategy balancing current needs with future sustainability. An integrated strategy usually requires the use of both structural and non-structural

measures (Abbas *et al.*, 2012). Structural measures are engineering works aim to moderate the stream channels, while non-structural are non-engineering based measures mainly aim at loss sharing (e.g. disaster aid and insurance) and loss reduction methods (e.g. preparedness, forecast, warning and land use planning) (Smith & Ward, 1998). In the study area, the structural measures, i.e. rainwater systems, have always been implemented with no attention non-structural solutions, for this reason, these solutions do not give quite meaningful results, and they need to be integrated with non-structural solutions, therefore, the early warning system will be one of these non-structural measures that should be considered.

Flood risk management is a continuous process, characterised by repeated activities: analysis of the flood risk, consideration of measures and policy instruments to reduce the risk, making policy decisions, implementing measures and instruments, monitoring their effects, etc. (Klijn, 2009). Flood risk analysis could be implemented in study area after risk identification, which will be an active tool to decision-makers to build the organisation strategy to reduce flash flood disaster risk.

To reduce flooding impacts, De Bruijn and Klijn (2001) state that resilient flood risk management strategy considers a set of measures such as the design of warning systems. Designing a guidance for a responsive warning system as it is one of the key measures to reduce flooding impacts in which the local government and communities are given sufficient time to respond to approaching flood, which contributes positively in reducing losses in life and properties.

Planning for the limitation of flood damage and choosing the proper methods to reduce losses incurred by flash flood requires that an evaluation of the level of flood risk in a given area to be carried out. Flood risk can be characterized in many ways, but three elements are crucial: (i) hazard, (ii) exposure (iii) vulnerability (APFM, 2007), these elements are known as factors of risk.

- **Hazard:** dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (ISDR, 2009a). It refers to the possible, future occurrence of natural or human-induced physical events that may have adverse effects on vulnerable and exposed elements. Natural hazard is natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage, and can be divided into three categories: geological, meteorological, hydrological (ISDR, 2009a). Floods is an example of hydrological hazards. Technological hazards are hazards originating from technological or industrial conditions that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and

services, social and economic disruption, or environmental damage (ISDR, 2009a). Technological hazards also may arise directly as a result of the impacts of a natural hazard event.

- **Vulnerability:** is the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (ISDR, 2009a). It refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events (IPCC, 2012). McEntire (2001) states that vulnerability is a dependant component of disaster. In order to mitigate disaster, therefore, vulnerability should be managed (Kanchana *et al.*, 2009). There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset) which is independent of its exposure. However, in common use the word is often used more broadly to include the element's exposure (ISDR, 2009a)

- **Exposure:** refers to the inventory of elements; people, property, systems, or other elements, present in hazard zones that are thereby subject to potential losses. Hence, if population and economic resources were not located in (exposed to) potentially dangerous settings, no problem of disaster risk would exist. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest (ISDR, 2009a). While the literature and common usage often mistakenly conflate exposure and vulnerability, they are distinct. Exposure is a necessary, but not sufficient, determinant of risk. It is possible to be exposed but not vulnerable (for example by living in a floodplain but having sufficient means to modify building structure and behaviour to mitigate potential loss). However, to be vulnerable to an extreme event, it is necessary to also be exposed (Cardona *et al.*, 2012). Moreover, Cardona (2004) stated that hazard and vulnerability cannot exist independently of each other. Additionally, Cardona assumed that since hazards cannot be modified; efforts aimed at reducing risk to a hazard could only be focussed on reducing vulnerability of the exposed communities or environments to that hazard. Kelman (2003) agreed with Lewis (1999) that, since vulnerability assesses the processes at work between hazard and risk, and since it is applicable to any hazard, targeting vulnerability will reduce overall risk to an acceptable level.

Flood risk is a function of exposure (the value of what can be damaged), hazard (the probability and intensity of a flood), and vulnerability (susceptibility of the building or contents to damage). These three elements are combined in one equation (see equation 2.1) (Kron, 2005).

$$Risk (R) = Hazard(H) \times Vulnerability(V) \times Exposure(E) \dots \dots \dots 2.1$$

FRM is essentially preventive management, which is about dealing with floods that are happening or are about to happen. However, FRM involves the development of flood warning systems that are essential for flood event management. FRM includes flood risk reduction, and must consider changes in the physical, socio-economic, and environmental characteristics of the flood-prone area and in its long-term strategies; therefore, FRM can be seen as part of an overall management policy for sustainable development. To manage flood risk, it requires a management system, which improves ability to cope with extreme rainfall events, and also with the change in the frequency and severity of these perturbations over time. FRM purpose is to create a balance between the socio-economic and physical characteristics of the system and the rainfall or peak discharges entering the system (De Bruijn *et al.*, 2007; Klijn, 2009).

Flood management strategy includes: (i) *pre-flood measures*, (ii) *flood forecasting*, and (iii) *post-flood measures* (Nektariosn & Karatzas, 2011). *Pre-flood measures* are determined by the aim of reducing flood risks in the long term. They can be characterised by the availability of time and resources (Schanze *et al.*, 2007). They provide the natural, institutional and social infrastructure for the viable management of a flood risk. Strategies for preventive flood management include: *technical measures* to control and manage the flood (small dams and projects on the retention and stabilisation of river banks); *regulating measures* for land use and the planning settlement; and *economic measures* for the regulation, promotion and communication (Water Directors, 2003).

*Flood forecasting- Warning System (FFWS)* includes the planning of a network of telemetric stations for recoding rainfall, meteorological parameters and river flow. This system can also provide a direct warning system for the development of an evacuation plan. (Green *et al.*, 2000). FFWS is used to increase flood warning time, reduce damage and save lives (Ford, 2001). FFWS can be effectively combined with other measures for flood prevention such as retention, land use and structural measures, flood emergency and public awareness. added that an effective and reliable system of flood forecasting and warning should be set up to inform, at respective level, flood authorities and citizens in threatened areas (Water Directors, 2003).

*Post-flood measures* promote the fast re-establishment of the affected regions and include measures of alleviation, re-establishment of the damaged infrastructure, and the revision of the effectiveness of the flood-prevention system. Authorities that have adopted a programme of readiness and a plan for mitigating the consequences can respond much more effectively in the case of a flood (Nektariosn & Karatzas, 2011). Post-flood measures are dedicated to recovery and the avoidance of further negative consequences. Their activities may include: (i) relief for the immediate needs of those affected by the disaster (ii) reconstruction of damaged buildings, infrastructure and flood defences (iii) recovery and regeneration of the environment and the economic activities in the flooded area, and (iv) review of the food management activities to improve the process and planning for future events in the area affected and more generally, elsewhere (Schanze *et al.*, 2007).

EC (2009) reported that flood risk management consists of systematic actions in a cycle of preparedness, response and recovery, and this should also be reflected in land management approaches. Sayers *et al.* (2013) stated that FRM is not a one-off activity, but it is a continuous process, characterised by repeated activities. Sayers *et al.* (2013) agreed with (EC, 2009) that FRM consists of: *before the event* (prevention and mitigation or planning, preparation), *event impact* (response), and *after the event* (recovery), which is known as flood risk management cycle as shown in Figure 2.7. Some studies like UNICEF (2008) consider that flood risk management cycle consists of five components: prevention, mitigation, preparedness, response, and recovery.

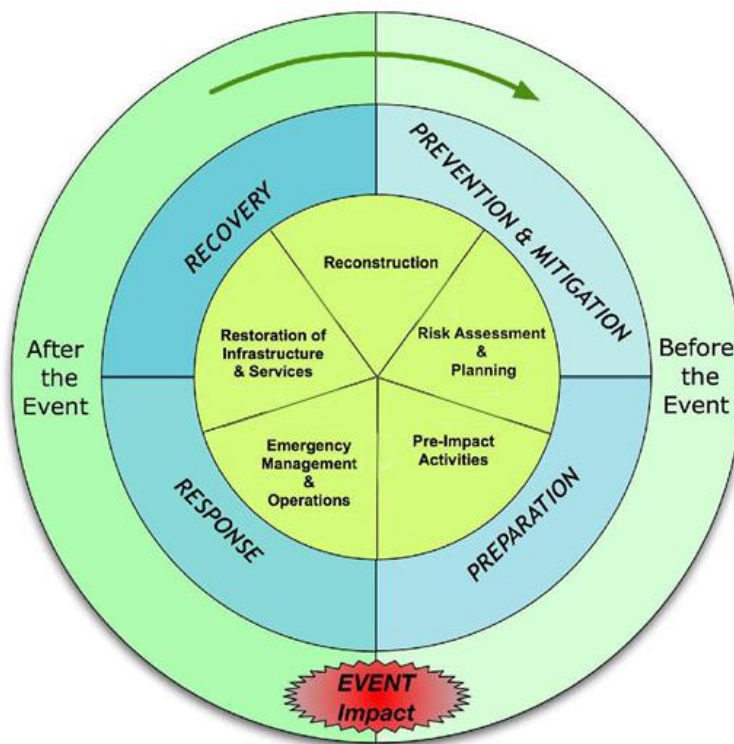


Figure 2.7: Flood Risk Management Cycle

Prevention methods look at structural measures, reforestation, watershed management and land use and building control. The mitigation approaches are conserving flood plains, special management and building regulation allowing for flood-proof construction. Preparedness activities include public awareness, EWS and flood mapping. Response plan includes warning system, evacuation and health services and rescue. Recovery plan involves rehabilitation of infrastructure, damage compensation, etc.

*Flood emergency planning* involves preparing for floods – regardless of the perceived level of protection – and planning the response during a flood emergency. One of the most important decisions is whether people should be evacuated or stay in or near their homes and businesses. The decision is based on the likely depth and duration of flooding, the warning time and the availability of local safe havens where people can stay during the flood event (Sayers *et al.*, 2013). Therefore, the availability of contingency plan will help to define the evacuation points, evacuation routes and ensure that these are maintained, shelter, evacuation priorities and procedure, and information on evacuation procedures and routes to all those who will be involved.

*Flood forecasting and warning*: the purpose of flood forecasting and warning is to provide as much advance notice as possible of an impending flood. It therefore forms a vital component of emergency planning, as implementation of an emergency plan will be triggered by flood warnings (Sayers *et al.*, 2013). *Responding to a flood*: the response to flood begins either when a flood warning is received or, if there is no warning, when flooding first starts to occur. Where an emergency plan exists, this should be implemented (Sayers *et al.*, 2013).

According to Schanze (2014) three tasks with specific components can be used for structuring the flood management activities (see Figure 2.8). The main tasks are: risk analysis, risk assessment, and risk reduction. *Risk analysis* provides a rational basis for flood management decision-making at a national scale and locally. It also provides information on previous, current and future flood risks. *Risk assessment* can provide consistent information to support the development of flood management policy, allocation of resources and monitoring of the performance of flood mitigation activities (Hall *et al.*, 2003). It deals with their perception and evaluation. *Risk reduction* is dedicated with to interventions with a potential to decrease the risks (Schanze *et al.*, 2007). This matches with the first priority of Sendai Framework for Disaster Risk Reduction (SFDRR) which indicates that policies and practices for disaster risk management should be based on an understanding of disaster



risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment.

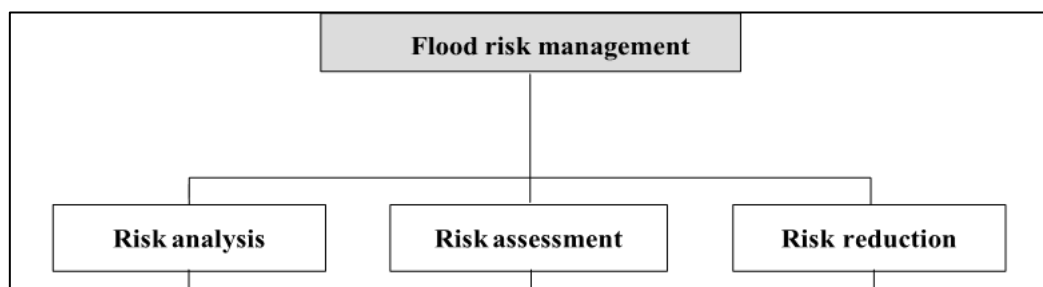


Figure 2.8: Components of Flood Risk Management

(Source: Adapted from Schanze et al. 2005)

## 2.5 Early Warning System (EWS)

ISDR (2009a, p. 12) defined Early Warning System (EWS) as “the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss”.

The term '*early warning system*' often refers to the technological monitoring, telemetry, and notification aspects of warning systems, and used to distinguish cases where a warning is able to be delivered in a time frame that permits protective action (Bobrowsky, 2013). EWS produces warnings whenever thresholds are exceeded. Threshold runoff is defined as the volume of effective rainfall of a given duration over the watershed of a small stream that is just enough to cause bankfull flow at the watershed outlet. It provides an estimate of the potential for excessive surface runoff of the small basins under soil saturation or land-surface impervious conditions (NOAA, 2010). Thresholds (trigger values) can be defined for rainfall, runoff, water level, and discharge and can be issued from each component of the chain that make up the EWS (Cools *et al.*, 2012).

In terms of preparedness, EWS recognises that it is important to look at the watershed or river basin as a system to understand where all the water causing flood comes from. Once river basins exceed their capacity, the excess water is spilled over to flat areas; and in a watershed system, the upstream rain can cause flooding at the downstream area (Antonio *et al.*, 2012). Upstream communities on a watershed often receive rains first and may be unaffected or less affected by floods than the communities downstream which offers them an important role in monitoring and alerting their neighbours downstream (IFRC, 2012). For example, flood CEWS in Chikwawa, Malawi, guided by Christian Aid, involve three communities that monitor river level gauges at key points on the river

(Mwanza, July, Kaloma stations). They exchange information by mobile phone and relay it to downstream villages. There, the alerts are transmitted to all concerned with megaphones and color-coded posters.

EWS's have been considered a cornerstone for disaster reduction (United Nations, 2006). It can reduce casualties and damages to moveable property substantially. The longer the time between the warning and the actual arrival of the flood, the better the residents can prepare by bringing their belongings and themselves to safe places (Antonio *et al.*, 2012). EWS produces warnings whenever thresholds are exceeded and can be issued from each component of the chain that composes the EWS (Cools *et al.*, 2012). Norbiato *et al.* (2008) established that there are at least two features that characterise flash flood forecasting; (i) the short lead time; and (ii) the need to provide local forecasts.

Sene (2008) suggested the various components of flood warning system as: detection, flood forecasting, thresholds, dissemination, response, recovery, review and preparedness, as shown in Table 2.7.

Table 2.7: Flood warning system components

Item	Component	Examples
Flood Warning	Detection	Monitoring meteorological, meteorological forecasting (e.g. nowcasting, numerical weather prediction)
	Thresholds	The meteorological conditions under which decisions are taken to issue flood warnings
	Dissemination	Procedures and techniques for issuing warnings to the public, local authorities, emergency services, etc.
Flood Forecasting	Rivers/Coasts	Models for forecasting future river and coastal conditions
Emergency Response	Response	Emergency works. E.g. temporary barriers, flow control, evacuation, rescue, incident management, decision support
	Recovery	Repair, debris removal, reuniting families, emergency funding arrangements Providing shelter, food, water, medical care, counselling
	Review	Review performance of all components of the system Recommendations for improvements
	Preparedness	Emergency planning, public awareness campaigns, training, systems improvements, flood risk mitigation

(Source: Sene, 2008, pp. 72)

Tompkins *et al.* (2005) stated that flood warning system is not a standalone to minimize the impacts of flooding, it should be coupled with emergency planning measures and contains an awareness

raising element. Therefore, these systems will be beneficial when every targeted person knows what the system of warning means, what the stages of warning are and what to do when the warnings are given. Coupling this measure with technologies, such as hazard mapping, will improve the effectiveness of flood warnings and will help to further raise awareness of local risk of flooding

### 2.5.1 Community-Based Early Warning System

Early warning system is one of the important tools that contribute to the prevention of flash floods and preparedness for hazards and threats, of any kind. It greatly enhances disaster risk reduction (DRR). A well-prepared National Society or non-governmental organization (NGO) will understand and promote the role of people-centred early warning systems (EWS) in reducing risk (IFRC, 2012).

A community-based early warning system is understood to be an effort by or with, but not for, a community to systematically collect, compile and/or analyse information that enables the dissemination of warning messages that when actionable can help the community (or others 'downstream') reduce harm or loss from a hazard (or threat) event (or process). Community-centred EWS necessarily comprises four key elements: (i) Risk knowledge (ii) Monitoring and warning (iii) Communication and dissemination (iv) Response capabilities (see Figure 2.9) (Phaiju *et al.*, 2010b).

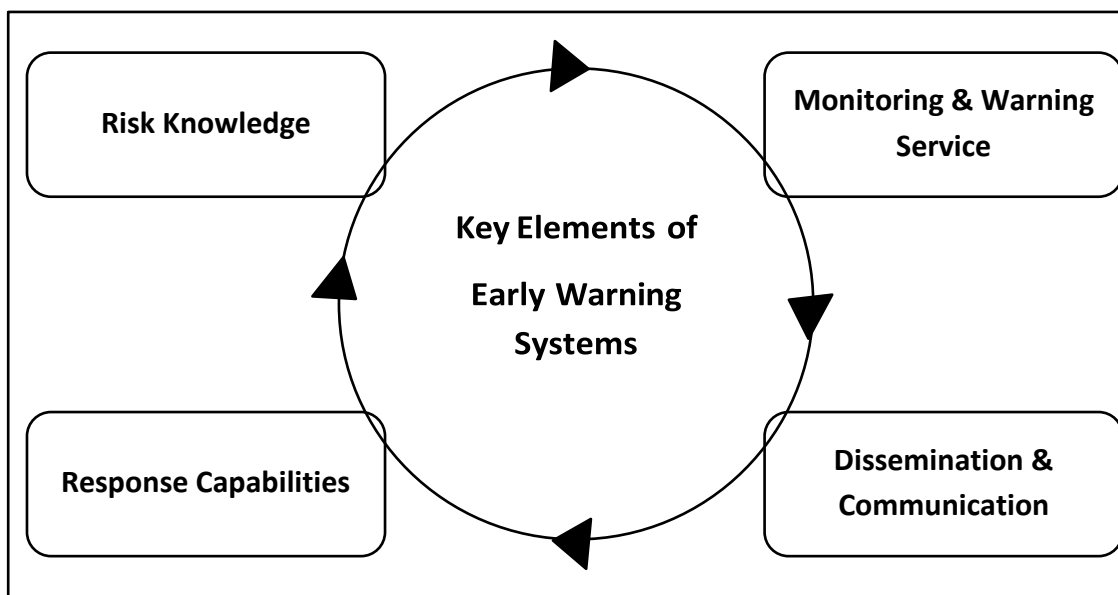


Figure 2.9: Key elements of community-based Early Warning System

Source: Adopted from ((Phaiju *et al.*, 2010, P. 29)

#### 2.5.1.1 Risk Knowledge

Risk knowledge builds the baseline understanding about risks (hazards and vulnerabilities) and priorities at a given level (IFRC, 2012). Risks arise when a hazardous situation collide with vulnerable circumstances at a particular location. A detailed assessment of the risks will be required through

systematic collection and analysis of data and should consider the dynamic nature of hazards and vulnerabilities arising from land-use change, environmental degradation, urbanisation and climate change. Risk assessments and maps help to understand the situation, motivate people, prioritize needs for developing early warning systems and guide preparations of disaster prevention and response measures (Phaiju *et al.*, 2010b, p. 29).

#### **2.5.1.2 Monitoring and Warning**

Monitoring is the logical follow-on activity to keep up-to-date on how those risks and vulnerabilities change through time (IFRC, 2012). Warning services lie at the core of the system. There must be a sound basis for predicting and forecasting hazards as well as reliable forecasting and warning system operating 24/7. Continuous monitoring of hazard parameters and contributing factors is essential to generate accurate and timely warnings. Warning services should be coordinated with stakeholders and relevant agencies to gain benefits of shared institutional, procedural and communication networks (Phaiju *et al.*, 2010b, p. 29).

#### **2.5.1.3 Dissemination and Communication**

Dissemination packages the monitoring information into actionable messages understood by those that need, and are prepared, to hear them (IFRC, 2012). Warnings must reach all those at risk including all vulnerable members of a community. Clear messages containing simple, useful and understandable information are crucial to enable proper understanding of warnings and responses in order to safeguard lives and livelihoods. It should be taken into account that some community members might not be able to hear or see the information or to follow the instructions by themselves and appropriate measures and actions should be taken accordingly. Community and district level communication systems must be pre-identified and appropriate authoritative mandates be established. The use of multiple communication channels can be necessary to ensure that as many people as possible are warned and to reinforce the warning message (Phaiju *et al.*, 2010b, p. 30).

#### **2.5.1.4 Response Capabilities**

Response Capabilities insists on each level being able to reduce risk once trends are spotted and announced. This may be through pre-season mitigation activities, evacuation or duck-and-cover reflexes, depending on the lead-time of a warning (IFRC, 2012). It is essential that communities understand their risks, respect and follow the warning and know how to react. Education and preparedness interventions play a key role in increasing knowledge. It is also essential that

contingency and disaster management plans be in place, that roles and responsibilities are clearly stated among community members, that resources including human resources are allocated and that standard procedures are well practiced and tested. All community members should be well informed regarding warning messages, when and how to react to the messages, steps to take to prepare themselves and their family, options for safe behaviour, available escape/evacuation routes, and best ways to avoid damage and loss of properties (Phaiju *et al.*, 2010b, p. 30).

### **2.5.2 Early warning systems related to Flooding**

As mentioned in the floods and flash flood section 2.3 of this chapter, in the last decades, many of the developed and developing countries exposed and are quite often exposing to floods and flash floods. These countries have lost many people and much of their national wealth such as infrastructure and economy. Therefore, many of developed countries have adopted early warning systems as one of the mitigation measures that might be a part of solving this tragedy.

The basic idea behind early warning is that the earlier and more accurately we are able to predict short- and long term potential risks associated with natural and human induced hazards, the more likely we will be able to manage and mitigate a disaster's impact on society, economies, and environment (UNEP, 2012). Effective early warning systems embrace the following aspects: risk analysis; monitoring and predicting location and intensity of the disaster; communicating alerts to authorities and to those potentially affected; and responding to the disaster. The early warning system has to address all these aspects (UNEP, 2012). Furthermore, a weakness or failure in any one part could result in failure of the whole system (ISDR, 2006a). This means that if the warnings were issued but the population is not prepared, or if the alerts were received but were not disseminated by parties receiving these alerts.

Monitoring and predicting provide the input information for the early warning process that needs to be disseminated to those whose responsibility is to respond (see Figure 2.10). Early warnings may be disseminated to targeted users or broadly to communities, regions or to media. This information gives the possibility of taking action to initiate mitigation or security measures before a catastrophic event occurs. When monitoring and predicting systems are associated with communication systems and response plans, they are considered early warning systems (Glantz, 2003).

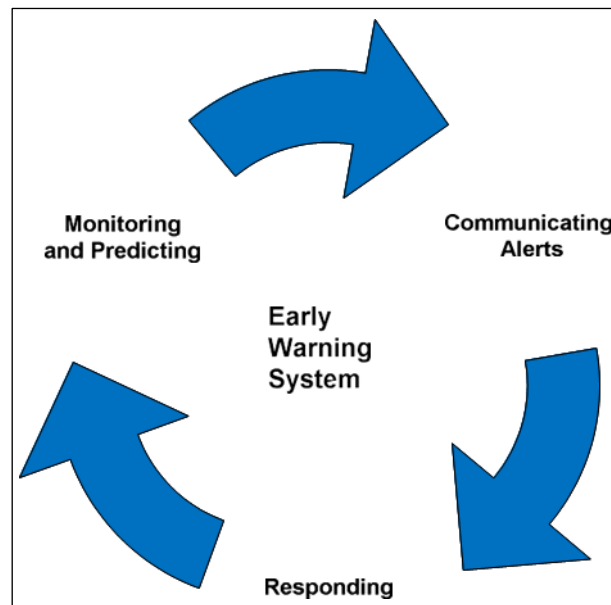


Figure 2.10: Early Warning System operational aspects

(Source: UNEP, 2012)

To be effective, warnings must also be timely so as to provide enough lead-time for responding; reliable, so that those responsible for responding to the warning will feel confident in taking action; and simple, so as to be understood (Grasso, 2006). An effective early warning system needs an effective communication system. Early warning communication systems have two main components: (i) communication infrastructure hardware that must be reliable and robust, especially during the disaster; and (ii) appropriate and effective interactions among the main actors of the early warning process, such as the scientific community, stakeholders, decision makers, the public, and the media (EWCII, 2003).

Many communication tools are currently available for warning dissemination such as; Short Message Service (SMS), email, radio, TV and web service. Information and communication technology (ICT) is a key element in early warning, which plays an important role in disaster communication and disseminating of information to organizations in charge of responding to warnings and to the public during and after a disaster. Redundancy of communication systems is essential for disaster management while emergency power supplies and back-up systems are critical in order to avoid the collapse of communication systems after disasters occur (Tubtiang, 2005). In addition, remote sensing satellites now provide a continuous stream of data. They are capable of rapidly and effectively detecting hazards such as natural hazards. Today, the decentralization of information and data through the World Wide Web makes it possible for millions of people

worldwide to have easy, instantaneous access to a vast amount of diverse online information (UNEP, 2012).

Systems used in the worldwide are based in sensor networks, websites, geographic information systems (GIS), radio, TV's, and SMS (Keoduangsine & Goodwin, 2012). Wireless sensor networks have been used for flood detection in Honduras, which is affected by heavy rain and hurricanes (Basha & Rus, 2007).

Flash flood forecasting subsystems can be divided into two broad categories; local flood warning systems (LFWS), based primarily on strategically placed rainfall and river gauges, and flash flood guidance (FFG) systems, are based upon a combination of *in situ* gauges, remote sensing data, and sometimes hydrologic models and rainfall forecasts from atmospheric models (NOAA, 2010).

### **2.5.3 Practices of EWS's for Floods and Flash Floods**

Basha and Rus (2007) stated that in developing countries, flooding results in massive loss of life and property. Warning communities of the incoming flood provides an effective solution to this by giving people sufficient time to evacuate and protect their property. Therefore, a range of early warning system solutions was adopted in developed and developing countries to reduce flooding impacts. Some of these warning systems have been reviewed here to demonstrate their effectiveness in mitigating the impacts of these floods.

#### **2.5.3.1 Demer Basin-Belgium flood forecasting system**

Flooding incidences are common across Belgium, and affect much of its infrastructure, farming practices, businesses and residents. Inhabitants of the low-lying Demer river basin had been in need of timely, accurate flood forecasts and warnings. The government responded to this need by commissioning a new forecasting system from a consortium of international consultants. The Demer basin, with an area of 2275 km<sup>2</sup>, covers the key flooding areas of the towns of Aarschot, Zichem and Zichem (Tate & Cauwenberghs, 2005).

Tate and Cauwenberghs (2005) argues that the system takes telemetry data from a large number of hydrological, meteorological, and hydraulic observation sites across the basin, along with radar rainfall forecasts. These data are fed through a network of complex hydrological and hydrodynamic models. Scheduled runs of the system take place at frequencies determined by the level of alert; runs are performed on a cluster of server computers, then results are available on client computers in the control room and via remote access. This gives operational basin managers fast, accurate, real-time flood forecasting and flood mapping based on high-resolution digital ground model

information, enabling identification of those streets and areas affected by flooding. The basin managers have several options for diverting flood waters in order to avoid or mitigate the effects of flood events in key areas. The forecast results underpin a decision-support system, giving basin managers the information they need to make informed judgements for disseminating flood warnings and altering their management of the river controls. Tate and Cauwenberghs concluded that enhanced computer power and modelling capability allow basin managers and engineers to carry out fast and accurate simulation of the key elements of the future behaviour of river, channel, and coastal systems. This supports mobilisation of emergency responses and provision of public flood warnings.

#### **2.5.3.2 Australian early warning system**

Early warning systems have been developed in Australia particularly for floods, bushfire, cyclone hazards where there is an opportunity for warnings to have (or may have) the greatest impacts. The Bureau of Meteorology (BOM) disseminates warnings, watches and advises on weather events such as severe thunderstorms, fire weather, coastal hazards, high winds, flood and tropical cyclone warnings and, in collaboration with Geoscience Australia, tsunami warnings. A significant number of warnings issued for natural hazards in Australia are issued by the BOM (Dufty, 2014). The Australian Government provides national leadership around emergency warning activity, contributing to a whole-of-nation, resilience-based approach to preventing, preparing for, responding to, and recovering from disasters (Attorney-General's Department, 2013). Researcher found that there has been considerable progress in Australian early warning systems over the past ten years. However, the research identified that further improvement could be made in some aspects of early warning systems such as raising low levels of community emergency preparedness in many Australian communities, designing effective flash floods warning systems, and understanding potential community response behaviours. Consistent evaluation of early warning systems – before and after emergencies – is also required.

#### **2.5.3.3 Global Flash Flood Guidance System (GFFGS)**

America has shown many successful examples in terms of early warning systems, in USA there are numerous locally operated ALERT networks but no national flash flood rain gauge/stream flow network in the United States (NOAA, 2010). The Hydrologic Research Centre (HRC), located in San Diego- California in the United states, has developed a Flash Flood Guidance System with Global Coverage (GFFGS) that can be used as a diagnostic tool by national meteorological and hydrological services (NMHS) and disaster management agencies world-wide to develop warnings for flash floods



(NOAA, 2010). The purpose behind this initiative is to improve the worldwide response by federal, state, and local governments, international organisations, non-governmental organizations, the private sector, and the public to the occurrence of flash floods. It is designed to be incorporated into NMHS operations and used along with other available data, systems, tools, and local knowledge to aid in determining the near-term risk of a flash flood in small streams and basins. The system can be used in its real-time mode or in a forecast mode. The important technical elements of the flash flood guidance system are: (i) Development and use of the bias-corrected satellite precipitation estimate field; and (ii) use of physically-based hydrologic modelling to determine flash flood guidance and flash flood threat (NOAA, 2010).

#### **2.5.3.4 Central America Flash Flood Guidance**

In the Central America, an early warning system for flash floods implemented, Central America Flash Flood Guidance (CAFFG), provides operational meteorological and hydrological services in seven Central American countries with timely guidance to issue effective flash flood warnings for small river basins (NOAA, 2010). This system is considered as the world's first regional flash flood guidance system.

NOAA (2010) argues that GFFGS can be applied anywhere in the world as it has been successfully demonstrated with the Central America Flash Flood Guidance system (CAFFG) currently operational for each of the seven countries in Central America and operational in Southeast Asia (called MRCFFG), whereas implementation is underway in Southern Africa, Zambia and Zimbabwe.

For the developing countries, early warning systems established in some countries, such as:

#### **2.5.3.5 Kenyan Flash flood early warning**

A conceptual flash flood early warning system is being developed in Kenya. Flash flood early warnings are based on a combination of the Flash Flood Guidance (FFG) method (Carpenter *et al.*, 1999; Georgakakos, 2006; Mogil *et al.*, 1978) in combination with a hydrological model. The system will be maintained and operated through a public-private partnership. The early warning system could significantly reduce the number of fatalities due to flash floods, improve the efficiency of disaster risk reduction efforts and play an important role in strengthening the resilience to climate change of developing countries in Africa (Hoedjes *et al.*, 2014).

#### **2.5.3.6 Flash Flood Manager in Egypt**

This project was presented by (Cools *et al.*, 2012; El Afandi *et al.*, 2013). The system is an early warning system called Flash Flood Manager (FlaFloM) for flash floods that has been developed for

Wadi Watier located in the Sinai Peninsula of Egypt. A hyper-arid area confronted with limited availability of field data, limited understanding of the response of the wadi to rainfall, and a lack of correspondence between rainfall data and observed flash flood events (Cools et al., 2012; El Afandi et al., 2013). The EWS was able to forecast the last two flash floods, on 24 October 2008 and 17–18 January 2010 with an underestimation for the 2008 event and an overestimation for the 2010 event (Cools et al., 2012).

#### **2.5.3.7 The Aburrá Valley Natural Hazard EWS (AVNHEWS)- Colombia**

The Aburrá Valley Natural Hazard Early Warning System (AVNHEWS) was designed to integrate existing disaster management infrastructure with new infrastructure to create an end-to-end early warning system to reduce the loss of life and suffering caused by floods, flash floods within the Aburrá Valley. AVNHEWS will also build national capacity in overall rainfall estimation and flash flood prediction throughout Colombia (NOAA, 2010).

The primary purpose of the AVNHEWS is to provide real-time guidance about the potential of (a) small-scale flash flooding throughout the Aburrá Valley and (b) large-scale flash flooding throughout the entire country of Colombia. The subsystem was designed to address the AVNHEWS goal of reducing suffering and the loss of life and property from the devastation caused by flash floods. The system's outputs will be made available to users as a diagnostic tool to analyse weather-related events that can initiate flash floods and then to make a rapid evaluation of the potential for a flash flood at a location. Evaluations of the threat of flash flooding will be done at hourly to six-hour time scales for basins from 25-50 km<sup>2</sup> in size within the Aburrá Valley to 100-300 km<sup>2</sup> in size for the rest of Colombia. Radar and satellite precipitation estimates will be used together with available local and regional in-situ precipitation gauge data to obtain bias-corrected estimates of current rainfall volume over the region (NOAA, 2010).

#### **2.5.4 Benefits of EWS's**

Teisberg and Weiher (2009) stated that there are seven factors that determine the gross benefits of EWS's for the various natural disasters:

- Frequency: If a flash flood occurs relatively frequently, and if the warning system works, there will simply be more opportunities for that system to produce its benefits.
- Severity- what is the magnitude of the risk to life or the damage to property that the hazard could cause? if the typical severity of that flash flood is greater, the benefits of a successful warning and response are likely (but not certain) to be greater.

- Lead-time: Lead-time between a warning and the actual occurrence of a disaster essentially determines the range of responses that one could take – more lead-time generally means that there is a wider range of possible responses to a disaster warning.
- Accuracy: If the warning is not very accurate, little or no response may be appropriate. On the other hand, if the warning is highly accurate, it will be rational for people to make significant and possibly costly changes in behaviour.
- Response costs: The possible responses to a flash flood warning will have different costs. Relatively low-cost responses are more likely to make sense than relatively high cost responses. High cost responses will make sense only when the potential flash flood is severe, the warning is accurate, and the response makes a real difference.
- Loss reduction: how much are the expected costs of the flash floor reduced, given the likely public response to the warning? The loss reduction depends on the intrinsic effectiveness of possible actions that may be taken in advance of the flash flood, as well as the anticipated degree or extent of public response to the warning.
- EWS cost: Net economic benefits of an EWS for flash floods also depends on EWS cost. If this cost is low relative to the gross benefits of the warning system, the net benefits of the system will be large, and conversely.

HR Wallingford (2006) stated that the advantages of flood warnings are that flood warning systems provide an advance warning of flood events which can potentially allow:

- The risk to life to be minimized;
- Evacuation of vulnerable groups;
- Residents to move assets (e.g. food, livestock, personal effects) to safer locations;
- Timely operation of flood control structures (e.g. storm surge barriers, temporary flood defences, etc.) to prevent inundation of property and land;
- Installation of flood resilience measures (e.g. sandbags, property flood barriers);
- Pre-event maintenance operations to ensure free channel conveyance.

In order for the benefits of an EWS to be high, a natural hazard must simultaneously satisfy several criteria: it must be frequent, severe, predictable with reasonable lead-time and accuracy, and there must exist cost-effective responses to warnings of an impending occurrence. If any one of these criteria is not met, the potential benefits from a warning system may be small or even zero (Teisberg & Weiher, 2009). Therefore, EWS helps to save lives and affected people, reduce damages, provides enough time to response, supports decision maker to take the right decision in the right time, raise

the local governmental institutions and local communities' preparedness and contribute to build their capacities.

Often the most difficult issue in assessing the likely benefits from an early warning system is predicting the actual public response that will be forthcoming when a flash flood warning is issued. Flash floods typically threaten large numbers of people who are ordinary people not trained in the process of making optimal decisions under uncertainty, and who are almost certainly unaware of the systematic biases that plague decision-making about uncertain events. In fact, it is often a major challenge to determine what response is optimal, and how closely the actual response can be expected to approximate the optimal one (Teisberg & Weiher, 2009). Therefore, the success of EWS will depend significantly on how local authorities manage the response flash flood. Failure to achieve a rational public response to a flash flood warning means that benefits of EWS will be wholly unaccomplished.

#### **2.5.5 Need to warn local authorities and communities of flash floods**

Given that early warning is the imperative of local authorities, local communities, in their auxiliary role to support public authorities in risk reduction, turn to early warning as one tool to protect life and assets, health and livelihoods. Therefore, actions should be taken to address the underlying causes of suffering, and to prevent and reduce the impacts, exposure, and vulnerability to flash floods by implementation of early warning system (IFRC, 2012). For local authorities and communities, early warning can play an important role to reduce the impacts of flash floods.

Local authorities have an obligation to protect all residents from risk to life and health, as well as protecting private and public properties. Local EWS is flash flood risk tool that local authorities can use to meet these obligations. National and local laws should ensure that government institutions have clear mandates for EWS at all levels, that they have sufficient resources to carry out their obligations, and that they are required to incorporate the voices of communities and civil society in their planning and implementation processes at all levels. Governmental institutions must be held accountable for ensuring that EWS reach the entire at-risk population, and are acted upon in a timely fashion (IFRC, 2012). Therefore, local authorities need information on the flash flooding that could threaten the region and identify the most exposed areas to these risks, in turn to issue warnings to citizens in areas at risk. The mitigation measures are also used to reduce the risk of flash flooding in the area, such as evacuations of citizens, and the construction of sandy dams to mitigate the flood. In return, communities need to be warned against the risk of flash floods and high-risk

areas in order to take preventive measures to protect themselves and their properties from of flooding risk and to move away from hazardous areas.

## **2.6 Summary**

This chapter reviewed the existing literature to capture the knowledge and understanding of the issues associated with natural disasters, floods and flash floods, disaster risk management, and early warning systems. By reviewing literature on natural disasters, especially flash flooding, it has been shown that these disasters have significantly affected people's lives and property. Millions of people have died and billions have been affected. These disasters have also caused a lot of damages to the private and public infrastructure estimated at billions of dollars, which has affected the economies of worldwide countries and the lives of their people.

The floods and flash floods, and their impacts at human lives and properties, were reviewed (section 2.3), and shows that these floods and flash floods were the most expensive natural disasters. The literature review shows that floods and flash floods impacts at the developed countries are less than impacts at developing countries because developed countries are adopting better mitigation measures, however, developing countries are adopting weak mitigation measures. It also reviewed and analysed the existing literature about the flash flood events and their impacts in Jordan in general and in Petra Region in particular.

Finally, early warning system, its elements and components are reviewed in section 2.5, in addition to the community-based early warning system, the early warning systems related to flooding and how the early warning system would be effective systems. Moreover, some practices of early warning systems in both developed and developing countries are reviewed to shed light at these systems and their contribution to disaster risk reduction.

It reveals a knowledge gap in the implementation of the risk management process in preparedness in terms of EWS's for flash floods guidance and its elements. Having established the literature review for disasters and floods at world level of the study, the next chapter reviews the flash floods in Jordan and Petra Region.

## **Chapter 3      Conceptual Framework**

### **3.1 Introduction**

Chapter 2 presented the literature review at the global level and local level (Jordan and Petra Region) in particular. This chapter describes the process adopted to develop the research conceptual framework. This chapter commences with justifying why the conceptual framework was proposed in this research, followed by the main issues that require addressing in the conceptual framework: (i) the importance of the EWS's for flash floods guidance (ii) The concept of the community-centred EWS for flash flood (iii) The need to warn the local authorities and communities of flash floods in Petra Region (iv) The crucial need to develop EWS for flash floods in the early warning system to enhance the local authorities and communities' preparedness and response to reduce flash floods impacts. Then the development of the conceptual framework was discussed under the main concepts, interrelation and boundary. Finally, the conceptual framework was discussed and the discussion included the phases and components of the EWS for flash flooding.

### **3.2 The need for a conceptual framework**

Miles and Huberman (1994, p. 18) defined a conceptual framework as a visual or written product, one that "explains, either graphically or in narrative form, the main things to be studied; the key factors, concepts, or variables, and the presumed relationships among them". Therefore, the conceptual framework of a research study for the EWS; the system of concepts, assumptions, expectations, beliefs, and theories that supports and informs research, is a key part of research design. Maxwell (2013) stated that conceptual frame represents the actual ideas and beliefs about research topic. Moreover, Yin (2014) adds that by conceptualising the investigated phenomenon, the researcher can illustrate the main concepts of the study, the ways they are interrelated, and the boundaries within which the concepts and interrelationships are applicable. Therefore, conceptual framework helps the researcher to: (i) link to the research problem and (ii) facilities in planning the research ahead. It acts as a primary model that helps to gain an understanding of what is out there that the researcher plans to study and of what is happening with these aspects and why (Maxwell, 2013). Maxwell added that the most important thing to understand about research conceptual framework is that it is primarily a conception or model of what is out there that researcher plans to study, and of what is going on with these things and why to help researcher to assess and refine his goals, develop realistic and relevant research questions, select appropriate methods, and identify potential validity threats to researcher conclusions.

Maxwell stated that there are four sources for the modules that researcher can use to construct a conceptual framework for his research study: (i) researcher experiential knowledge, (ii) existing theory and research, (iii) researcher pilot exploratory research, and (iv) though experiments. Therefore, it is important to have a framework which represents how the individual researcher conceptualises his/her research, in order for the study to be developed productively. Considering the factors previously mentioned, researcher has developed the conceptual framework of the research to be investigated.

### **3.3 Main issues for conceptual framework development**

In this research, the flash flood risk is viewed as a combination of hazard, vulnerability and exposure, besides the impacts of the flash floods. It became evident following the discussion on flash flood risk that the study area as viewed in literature (section 2.3.4) is exposed to hazard of flash flood, and their residents are vulnerable to the flash flood. Through reviewing the available literature on the disaster risk management (section 2.4), the risk of the flash flood risk requires a mitigation measures to reduce this risk. Early warning system as reviewed in section 2.5, is a mitigation tool to reduce flash flood risk that may threaten study area's residents and properties. Therefore, researcher reviewed the concept of the community-based EWS, the EWS related to flash flooding, the practices of EWS, and the benefits of the EWS (section 2.5). These concepts, assumptions, expectations, beliefs, and theories that supports and informs research, are forming the conceptual framework of this research.

The main areas of the research have been identified through a comprehensive literature review which presented in chapter 2 (sections 2.3, 2.4, and 2.5). The main identified issues can be summarised as following:

- The importance of the EWS's for flash floods guidance (research problem section 1.2 and Early Warning System section 2.5);
- The concept of the community-centred EWS for flash flood (section 2.5.1);
- The need to warn the local authorities and communities of flash floods in study area (section 2.5.5)

These key areas will be discussed in the subsequent sections below.

#### **3.3.1 The importance of the EWS's for flash floods guidance**

The flash floods occurrence and impacts are increasing, results both of the increase of the size and vulnerability of exposed populations as well as an increase in frequency and severity of hydro-

meteorological hazard (WMO, 2014). The need to establish EWS is to protect lives and properties, and it is one of the key elements in any disaster reduction strategy, besides the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response (ISDR, 2006a). This tool is a key factor in which the mitigation plan of the flash flood of the concerned parties might succeed. Pre-disaster, local authorities and communities will definitely need to prepare to respond when flash flood occurs. For people at risk, they need to adopt mitigation measures to protect themselves and their properties. UNISDR (2010) argues that the level of awareness of the need to establish EWS's for natural hazards (flash floods) has been increasing in the last years particularly since the 2004 Indian Ocean tsunami, therefore, it has highlighted early warning as a major component of disaster risk reduction in the Hyogo Framework for Action 2005-2015. UNISDR adds that effective EWS are in great demand for several reasons: extreme weather events are expected in future due to current impacts of climate change, rapidly expanding urbanisation and increasing environmental degradation.

EWS for flash floods guidance probably is the most important tool that might contribute to reduce flash flood impacts and vulnerability at all levels in the Petra region. The guidance would be a key element that can provide the necessary information and strategies to the concerned authorities and communities that are at risk to enable them to be proactive, better prepared, equip them of the knowledge of the hazards at the locality, community vulnerabilities, and imminent risks and disasters, to receive warning messages, and mobilise their response capabilities to reduce risks. Furthermore, it helps to reduce economic losses by allowing people to better protect their assets and livelihoods. Early warning information allows people to make decisions that contribute to their own economic self-sufficiency and their countries' sustainable development (ISDR, 2006a).

### **3.3.2 The concept of the community-centred EWS for flash flood**

As mentioned earlier (section 2.5.1), complete and effective community based early warning system comprises four inter-related elements: risk knowledge, monitoring and warning service, dissemination and communication and response capability (see Figure 2.9). A weakness or failure in any one part could result in failure of the whole system (IFRC, 2012). In addition, the early warning is highlighted as a major component of disaster risk reduction in the Hyogo Framework for Action 2005-2015, the Framework emphasizes that early warning systems must be centred on the needs of people which means that warnings must be timely and understandable to those at risk (UNISDR, 2010). The objective of people or community-centred EWS's is to empower individuals and



communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment (UNISDR, 2010). Within this concept, communities are not only positioned as the object of EWS, but should be empowered to their own system, because citizen participation is a key principle of disaster risk reduction and resilience building (Whittaker *et al.*, 2015). Furthermore, communities must be aware of the warning service and know how to respond to warnings, besides designing educational and preparedness programmes to target groups of local authorities and communities.

### **3.3.3 The need to warn local authorities and communities in Petra Region**

The local government of Petra Region has the primary responsibility to look after the welfare of its citizens according to laws and regulations. Thus, the local government has the primary legal responsibility and authority to warn its citizens and help them to prepare for, response to, and recover from disasters.

It is crucial to communicate with the public to know that they understand the nature of the hazards, the risks to personal safety and property, and the steps to reduce those risks. This requires: raising public awareness and effecting behavioural change in the areas of mitigation and preparedness, deployment of stable, reliable, and effective warning systems, and development of effective messaging for including favourable community response to mitigation, preparedness, and warning communications (NOAA, 2010).

## **3.4 Development of the conceptual framework**

This section elaborates how the conceptual framework is structured. It involves the identification of the main concepts elicited from the literature review, the interrelationship among these concepts, and their boundaries.

### **3.4.1 Main concepts**

The previous section (section 3.3) has indicated the main issues that contribute to the main concepts in developing the conceptual framework. As demonstrated earlier in section 3.3.1 that EWS for flash flooding is the key factor for reducing flash flood risks and a major component in disaster risk reduction. It is recommended that people at risk should adopt EWS as a mitigation measure to protect themselves, their properties and their assets. Community-centred EWS for flash flood, which is of the methods of empowering individuals and communities threatened by hazards to act in case of event, can produce many advantages. However, this method is still facing some problems due to the role of reducing risks or responding to risks which is given to the local government,

besides the lack of community involvement in planning to reduce risks. Implementation of this guidance will enhance the success of community-centred EWS and then enhance the region's resilience.

### **3.4.2 Interrelation**

This research combines two different environments; (i) disaster risk management and (ii) the best practices of the disaster risk management in flash flood. In disaster risk management cycle, one of the phases is the preparedness, construction of EWS's is a part of the preparedness phase. EWS for flash floods guidance is part of preparedness phase, and a community-based approach in one way of warning people at risk to respond to flash floods and protect themselves.

The flash flood early warning system has many advantages as stated by (Rogers & Tsirkunov, 2011): give people time to flee from flash flood; enable local authorities to evacuate or shelter large numbers of people in advance of flash flood; enable a faster response to problems of flash flood. To minimise the negative impacts of flash flood, the EWS needs to be established. This starts with identifying the risk, then assessing the risk, disseminating the risk and response. By this way, the flash flood risk can be reduced and mitigated.

### **3.4.3 Boundary**

This study is conducted in Jordan- Petra region, a region that severely exposed to flash floods over years and needs infrastructure reconstruction. It is crucial to have a tool that helps local government and communities to reduce flash floods impacts.

## **3.5 Conceptual framework**

The conceptual framework for this research, which is shown in figure 3.1 is developed by combining the main concepts (section 3.4.1), their interrelations (section 3.4.2), and their boundaries as discussed in section 3.4. The next paragraphs provide more details.

Flood warning systems provide a well-established way to help to reduce risk to life, and allow communities and the emergency services time to prepare for flooding and to protect possessions and property (Sene, 2008). As the early warning system is a way of detecting threatening events in advance, it enables the public to be warned en-masse so that actions can be taken to reduce the adverse effects of the event (Linham & Nicholls, 2010). Moreover, the essential aim of early warning system is to reduce exposure and vulnerability to flooding.

The purpose of an early warning system is to detect and forecast threatening flood events and alert the public in advance to be capable to undertake appropriate responses to minimise the impact of

the event. This is a particularly important system in developing countries, where flooding results in massive loss of life and property (Linham & Nicholls, 2010). Furthermore, having warnings for flash floods is an important adaptive measure due to the difficulty of protection at a large scale which may cause environmental or social impacts in addition, the high cost of construction measures.

The conceptual framework here identifies the initial conceptualisation of the interactions between early warning systems that are sympathetic towards the specific community living in tourist areas alongside some of the communication cues that would work within such a diverse community within the Petra region. Some of the specific elements of conceptual framework for this study are drawn from the existing frameworks/practices as shown in Table 3.1

Table 3.1: Elements of conceptual framework drawn from existing practices

Element	Framework/Practice
a. Forecasting and warnings b. Disseminating flood warnings and altering	Demer Basin-Belgium flood forecasting system
a. Disseminates warnings b. Detection c. Warning d. Response e. improvement	Australian early warning system
a. Improve response b. Forecasting	Global Flash Flood Guidance System (GFFGS)
a. Forecasting b. Detection	Flash Flood Manager in Egypt
a. Forecasting b. Detection c. Improvement	The Aburrá Valley Natural Hazard EWS (AVNHEWS)- Colombia
a. Forecasting b. Warning c. Response d. Recovery	(Linham & Nicholls, 2010; Sene, 2008)

These elements, derived from early warning systems used in some world's countries, fall within the stages of flood risk management; preparedness, mitigation and prevention, response and recovery. In this context, these components, the results of literature reviews for flash flood events and their effects on the study area, in addition to the researcher's experience, shaped the initial conceptual framework and its phases. Researcher has shaped this framework for two phases within the flood warning process.

The flood warning process would then have two phases: (1) flash flood warning and (2) response. These phases eventually consist of several sub-phases, which are linked through the dissemination of warnings, as shown in Figure 3.1.

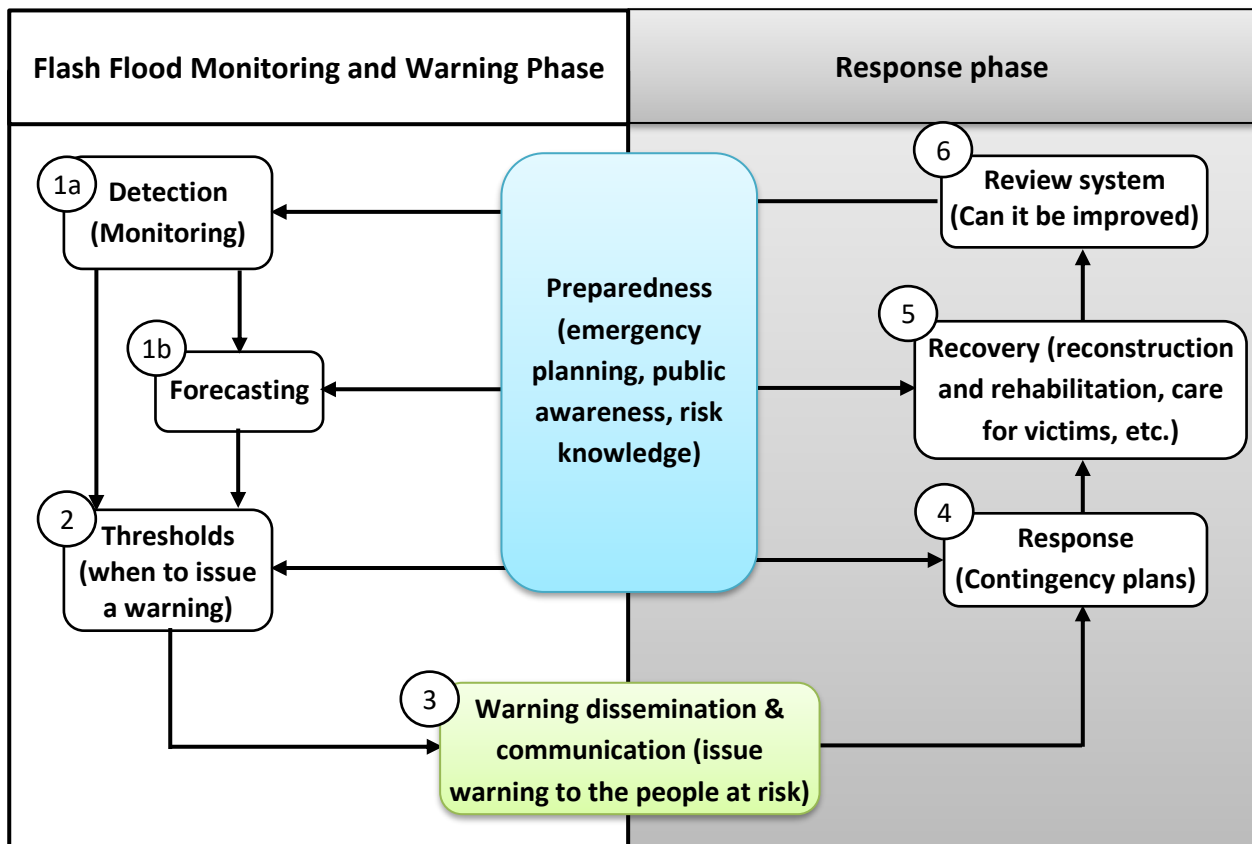


Figure 3.1: Conceptual framework for research

### 3.5.1 Flood monitoring and warning Phase

It needs persistent monitoring of meteorological conditions, which allows detection and assessment of the threatening events to take place before it hits a community. Forecasts may also be made to help decision-maker model how an event is likely to develop, how significant it will be upon arrival, and what sections of the community are likely to be at risk (Linham & Nicholls, 2010). Monitoring weather conditions is needed because simple detection of an event will not provide adequate time to undertake proper response. To achieve monitoring and forecasting, Linham and Nicholls (2010) added that it is likely that a food warning system will include meteorological and tidal detection systems and river and coastal flood forecasting models.

Sene (2008) stated that most flooding problems are linked to atmospheric conditions, and observations or forecasts of rainfall and other parameters often provide the first indication of

potential flooding. The flood warning and monitoring and warning phase consists of the following sub-phases:

#### **3.5.1.1 Detection (Monitoring) (1a)**

The real-time measurements of meteorological conditions, to guide decision making. This may include information on rainfall, tidal levels, and river levels. Remote sensing techniques and satellite may also be used (Sene, 2008). Meteorological information for flood warning and forecasting applications would be (i) measurements at selected locations using rain gauges, automatic weather stations (ii) Remote Sensing based on satellite observations, weather radar etc.

#### **3.5.1.2 Forecasting (1b)**

Is the application of science and technology to predict the state of the atmosphere for a given location and at a given time. Weather forecasting covers a wide range of numerical, empirical, observational and other techniques, and in operational forecasting the final decisions on the forecasts to issue are often taken based on a combination of these approaches (Sene, 2008). Sene added that for flood forecasting and warning applications, the following two approaches are of particular interest:

- Numerical Weather Prediction models that are for rainfall forecasts for input to rainfall runoff models. Typical maximum useful lead times can be 3-5 days or more.
- Nowcasting systems that provide short time forecasts based on a combination of weather radar, satellite, and other observations models.

#### **3.5.1.3 Thresholds (2)**

Flooding thresholds are the values at which flooding occurs. Threshold values may be set based upon experience or analysis of historical data, or using conceptual, data based or process based modelling studies. Observations or forecasts of heavy rainfall often provide the first indication of likely river flooding. Therefore, rainfall amounts can be used directly to initiate flood warning (Sene, 2008). When an event overrides a given threshold, system will issue a warning. The warning will be disseminated to the 'at risk' people via media, civil defence, PDTRA, community leaders, and basic signals such as sirens, billboards, or flags. Each of these channels will play its role.

#### **3.5.2 Dissemination (3)**

Flood warnings may need to be issued to the public, emergency services, local authorities and others with an interest in when and where flooding is likely to occur, or who are involved in the emergency response (Teisberg & Weiher, 2009). Dissemination techniques can broadly be separated into

indirect methods, community based methods, and direct methods, with some alternative classification schemes including use of the terms General and Specific (Emergency Management Australia, 1999). *Direct methods* provide a warning targeted at specific individuals or organisations, and have the advantage in some cases of confirmation that the recipient has received the warning, which is particularly important for the representatives of communities, local authorities, emergency services and other key responders; i.e. telephone, cell phone (voice, text), door knocking, fax, telex, pagers, two-way radio, email, leaflet drops. *Indirect warnings* by contrast provide a more general warning and can potentially reach large numbers of people; i.e. television, radio, teletext, telephone help line, RSS, and newspapers, whilst *community based methods* fall in between these two extremes; i.e. sirens, fixed, mobile or helicopter loud hailers, flags, and billboards (Sene, 2008).

The content and wording of warning messages must provide a clear and accurate description, in familiar language, and ideally contrasting the severity of the current situation to recent events which people may remember or can relate to. The warning should also include the time of issue and the location and expected time and duration of flooding, recommended actions, and the time for the next update (Sene, 2008).

If warnings can be disseminated to the public, it will also be possible to give communities advice on what to do in the event of a flood, as well as providing further information to limit losses. This may include areas to be evacuated, evacuation routes and the location of refuges for evacuees. It is likely that advice and guidance can be issued through the same channels used to notify communities of the flood risk as well as being made available prior to flood events (Linham & Nicholls, 2010).

### **3.5.3 Response phase**

After the at-risk population, have been warned, the second stage of the flood warning service is initiated; the response. People in the hazard zone are required to take action in cooperation with local authorities to minimise their exposure to the hazard and to reduce the social consequences of flooding (Linham & Nicholls, 2010). It is possible to gain efficiencies from collective systems to predict flash floods. However, such predictions create no benefits unless there is an appropriate response, and the appropriate response is largely something that takes place at the local level. The mechanics of responding to warnings are likely to be somewhat different depending on the lead-time between issuing a warning and the occurrence of the actual event (Teisberg & Weiher, 2009). However, Teisber and Weiher added that even if a threat is successfully communicated with enough lead-time for people to take action, it is not always easy to get the appropriate response from the people who are in danger.

### 3.5.3.1 Preparedness

The effectiveness of response to a flood event can be improved if an emergency plan has already been prepared, so that all participants understand their roles and responsibilities, including the overall chain of command. The potential disruption from flooding also needs to be considered, including the possibility of communication, instrumentation, computer and other systems failing, and access and evacuation routes being cut by flood water.

**Flood emergency planning:** Flood Emergency Plans describe the actions to take between, during and following flood events, and typically cover operational procedures, emergency response assets, contact details for key staff, health and safety issues, procedures for liaison with the media and the public, and information on safe access and evacuation routes and shelters (Sene, 2008).

Information on roles and responsibilities, and inter-agency coordination, is often an important consideration in developing flood emergency plans.

At community level (WMO, 2006), plans might include:

- Identifying and maintaining of safe havens, safe areas and temporary shelters
- Putting up signs on routes or alternate routes leading to safe shelters
- Informing the public of the location of safe areas and the shortest routes leading to them
- Having all important contacts ready
- Making arrangements for the damage and needs assessment team and health team
- Setting up community volunteer teams for a 24-hour flood watch
- Improving or keeping communication channels open to disseminate warnings
- Distributing the information throughout the community

In emergency planning guides, some key points which are often emphasised include: command, key contacts, resilience, vulnerable groups, transient populations, community engagement, health and safety, and continuous improvement.

**Risk Assessments:** Risk assessment involves assessing and mapping key hazards, vulnerabilities and exposure (UNISDR, 2005). Therefore, community actors should have sufficient awareness, information and understanding of risk (vulnerability and hazards). ISDR (2006b) emphasises that all risks must be well known and that risk maps and data are widely available. Moreover, Sene (2008) stated that one key stage in developing a flood emergency plan is to assess the flood risk, and to tailor the response to the level of risk. Flood risk can be expressed in terms of the probability of flooding and the likely impacts. Sene added that risk assessment techniques are also increasingly

used to assess the resilience of response procedures, together with developments in information technology for the spatial analysis and visualisation of flood extent relative to properties, infrastructure and transport routes.

**Public awareness:** It is important that appropriate actions are communicated to the public through awareness raising campaigns, prior to an emergency. Doing so, will mean actions can be quickly taken, helping to mitigate the consequence of flooding to the greatest degree (Linham & Nicholls, 2010). Public education campaign is a necessary part of any successful early warning system for flash floods; indeed, better public awareness alone may save large number of lives (Teisberg & Weiher, 2009).

#### **3.5.3.2 Response (Contingency plans) (4)**

Flood warnings provide local authorities, the emergency services, the public and others with time to take actions to reduce the risk from flooding, and information on the likely extent and locations of flooding. Actions which can be taken before a flood starts include installation of temporary defences, operation of flow control structures, protection of personal property, evacuation of people from areas at risk, and positioning of emergency vehicles and other assets in locations which may become inaccessible due to flood waters (Sene, 2008). People are required to take actual actions that are likely to reduce and mitigate flood impacts at themselves and their properties. Linkham and Nicholls stressed the importance of communicating the appropriate actions to the public through awareness raising campaigns, prior to an emergency. Doing so, will mean actions can be quickly taken, helping to mitigate the consequences of flooding to the greatest degree.

Teisberg and Weiher (2009) stated that if sufficient time is available, warnings are normally escalated from an initial advisory that flooding is possible, through to a full flood warning. The receipt of an advisory or warning is usually the trigger to activate a flood emergency plan (if one exists), and to commence preparatory actions. These actions can include mobilisation of staff and equipment, establishing a command centre, and issuing warnings to the media and public.

#### **3.5.3.3 Recovery (5)**

Recovery is the actions taken to make property safe, restore utilities (if applicable), remove debris, decontaminate sites, return people to their properties, reuniting families, emergency funding arrangements, providing shelter, food, water, medical care, and counselling. Flood emergency plans usually also cover the actions needed in the aftermath of an event (the recovery phase), including which organisation(s) will assume responsibility for repairs, debris removal, reuniting families,



emergency funding arrangements, and providing shelter, food, water, medical care, counselling, support to businesses, and restoration of services if interrupted (power, water, communications etc.) (Sene, 2008).

#### **3.5.3.4 Review system (6)**

Reviews of flood warning systems are often required following major flood events, and may form part of a programme of continuous improvement. Performance monitoring should ideally cover all aspects of the system, including detection, forecasting, dissemination, and response to warnings, together with feedback from users on satisfaction with the system.

The lessons learned from post event assessments, and recommendations from regular reviews, can then guide future investments, and provide baseline information for use in economic assessment and prioritisation exercises. However, improvements need not necessarily require significant investment, and much can be gained from improving operating procedures, and closer collaboration between the various participants in the flood warning process, including communities and their representatives.

An effective flood warning service requires cooperation between different agencies, such as the government, relief agencies and local communities. As such, this approach not only provides technical challenges but also, organisational ones (Linham & Nicholls, 2010). Sene (2008) stated that effective warning service requires some of the essential components as shown in Table 2.7.

It is important to note that a flood warning system is not a standalone response to minimisation of the impacts of coastal flooding. An early warning system should be coupled with emergency planning measures, such as the provision of evacuation routes and flood shelters, and should also contain an awareness raising element. These systems are only useful when everybody knows what the system of warning means, what the stages of warning are and what to do when the warnings are given (Tompkins *et al.*, 2005).

### **3.6 Summary**

This chapter presented the development of the conceptual framework for the study. The model was based on the: (i) literature review and the initial knowledge and (ii) understanding of the researcher on the areas. The framework was initially developed as Figure 3.1 and later after the first phase of data collection, the model was further refined and developed with more details that could be applied to a project. The left side of the conceptual model consists of the flood monitoring and warning phase towards the monitoring and warning. Meanwhile, the right side of the model

illustrates the second phase; response phase, which consists of different components involved in response phase such as response, recovery and review. The two phases were linked by dissemination and communication of the warning. Moreover, preparedness interlinks both phases. Initially, the main issues were defined as: the importance of the EWS guidance, the concept of the community-centred EWS, and the need to warn authorities and communities. Next, the integration of three factors to develop the framework: the main concepts used to build the conceptual framework, the interrelationship between the disaster management and the best practices of the risk management of flash flood, and Petra Region in Jordan as the boundaries of this study.

Having discussed and developed the conceptual framework for this study, the next chapter describes the process in achieving the aim and objectives of this study: research methodology.

## Chapter 4 Research Methodology

### 4.1 Introduction

This chapter describes the research methodology adopted in accomplishing the research aim and objectives. It starts with an introduction, a brief presentation of research problem, the aim, objectives, and the research question. The "research onion" model as suggested by Saunders *et al.* (2012) is adopted therein. Researcher then details the research philosophy, approach, design, methodological choice, research strategy and research procedure and techniques.

It is worth mentioning that the components of the conceptual framework explored and discussed in the previous chapter contribute effectively to the achievement of the fourth objective of the flash Flood Early Warning guidance and the fifth objective of developing a guidance for an effective early warning system for flash floods. It also answers the second part of the fourth research question, "What are the empirical elements of the guidance within early warning system for flash flood?"

### 4.2 Initial stimulus

The researcher's enthusiasm to study and develop a guidance for the flash flood early warning system in Petra came from two strong incentives. First, being a coordinator for "Enhancing institutional capacities to reduce disaster risk and integrate climate change in Jordan" project with UNDP- Jordan for three years. Second, directing the disaster risk reduction unit in PDTRA which provided researcher with a good background about research subject.

### 4.3 Research methodological framework

Methodology is the systematic, theoretical analysis of the methods applied to a field of study (Irny & Rose, 2005). Research methodology refers to the procedural framework within which the research is conducted (Remenyi *et al.*, 1998). Methodology is an overall approach to a problem which could be put into practice in a research process, from the theoretical underpinning to the collection and analysis of data (Remenyi *et al.*, 2003). Collis and Hussey (2014) defined methodology as the overall approach to the entire process of the research, or it is an approach to the process of the research encompassing a body of the methods. It is also the way research techniques and methods are grouped together to provide a coherent picture (Easterby-Smith *et al.*, 2012). Saunders *et al.* (2012, 2015) further stated that the theory of how research should be undertaken, including the theoretical and philosophical assumptions upon which research is based and the implications of these for the method or methods adopted, and refers to the theory of how research should be undertaken.

Research is composed of stages, summarised as: (i) conceptualisation (including conceiving the research question, recognising the philosophical position, determining the approach and formulating the design) and (ii) implementation (sampling, data collection and data analysis), interpretation and outcomes (Saunders *et al.*, 2012). The research topic and the specific research questions are the main criteria, which affect the appropriate methodology to be adapted (Remenyi *et al.*, 2003). According to the above definitions, research methodology is about addressing the problems to be investigated in a research study and for this reason it varies accordingly.

The overall research methodology was presented by Saunders *et al.* (2007) in a form of an 'onion' to illustrate the different stages that must be considered in developing research, as shown in Figure 4.1. When this onion is viewed from outside, each layer of the onion describes a more detailed stage of the research process (Saunders *et al.*, 2007). The research onion provides an effective progression through which a research methodology can be designed. Its usefulness lies in its adaptability for almost any type of research methodology and can be used in a variety of contexts (Bryman, 2012). The research onion consists of six layers: philosophy, approaches, choices, strategies, time horizon, and data collection and analysis.

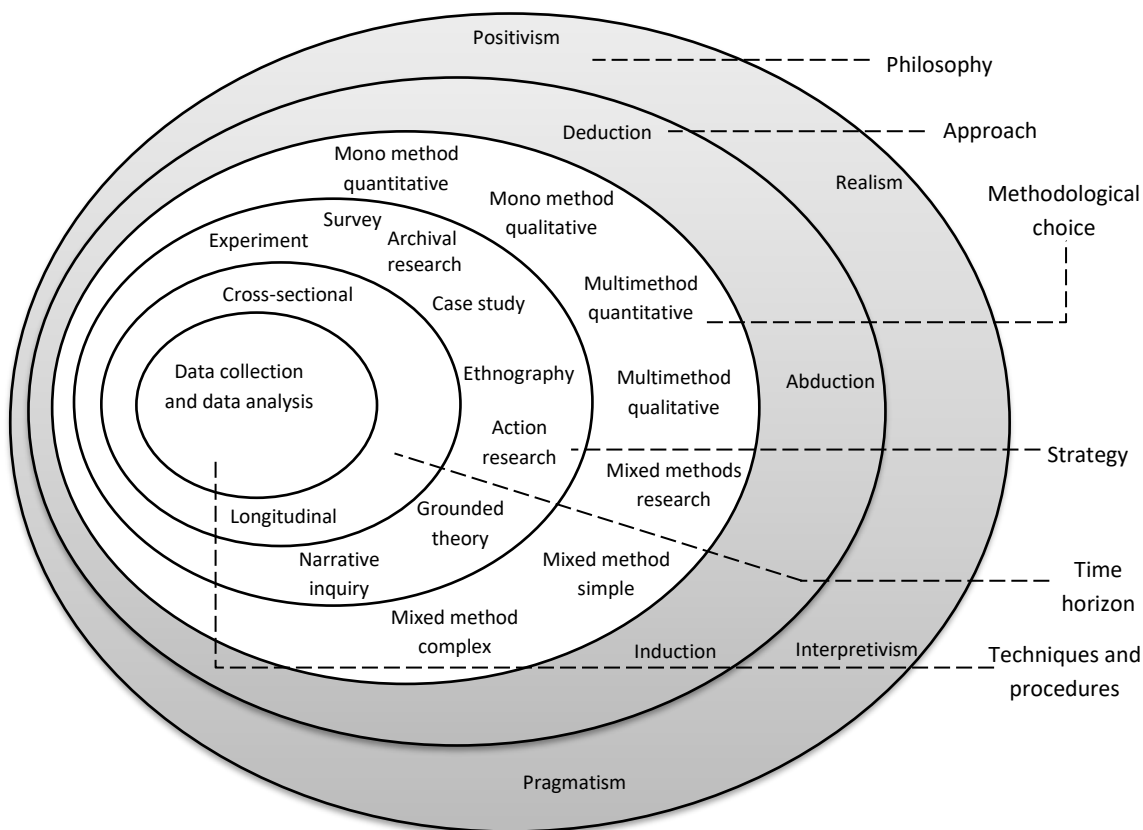


Figure 4.1: Research Onion

(Source: Saunders *et al.* 2012)

The research onion suggested by Saunders *et al.* (2007) is somehow close to the hierarchical model developed by Kagioglou *et al.* (2000). The following sections describe the layers of research onion regarding this research.

#### 4.4 Research Philosophy

Research philosophy relates to the development of knowledge and the nature of that knowledge. It contains important assumptions about the way the researcher views the world. These assumptions will underpin research strategy and the methods researcher choose as part of that strategy (Saunders *et al.*, 2012). There are three main philosophical positions that underlie the designs of management research: Epistemology, Ontology and Axiology. Pragmatism view argues that the most important determinant of the research philosophy any researcher adopts is the research question (Saunders *et al.*, 2012). The explanation of each assumptions and the philosophical stance of the research is described in the following subsections.

##### 4.4.1 Ontology

Ontology refers to assumption about the nature of reality (Bryman & Bell, 2011; Easterby-Smith *et al.*, 2012; Saunders *et al.*, 2015). Its assumptions shape the way in which researcher sees and studies research objects such as organisations, management, individuals' working lives and organisational events and artefacts (Saunders *et al.*, 2015). The ontology continuum is objectivism and subjectivism (Saunders *et al.*, 2009, 2012).

According to Saunders *et al.* (2012, pp. 131-132), **objectivism** represents the position that social entities exist in reality external to and independent of social actors, while **subjectivism** asserts that social phenomena are created from the perceptions and consequent actions of social actors. Furthermore, Collis and Hussey (2014) argue that objectivism sees the reality as objective and singular, a part of the researcher, whilst subjectivism defines where reality is subjective and multiple, as seen by participants.

Easterby-Smith *et al.* (2012) divided the ontology into four assumptions: realism, internal realism, relativism, and nominalism.

Table 4.1 shows how the ontology assumption describes the truths and facts. Within social science, the debates about ontological assumptions are primarily between the positions of internal realism, relativism and nominalism, and answer depends both on the topic of enquiry and preferences of the individual researcher.

Table 4.1: Four different ontologies

Ontology	Realism	Internal Realism	Relativism	Nominalism
Truths	Single truth	Truth exists, but is obscure	There are many 'truths'	There is no truth
Facts	Facts exist and can be revealed	Facts are concrete, but cannot be accessed directly	Facts depend on view point of observer	Facts are all human creations

(Source: Easterby-Smith *et al.*, 2012, P. 19)

#### 4.4.2 Epistemology

Epistemology is a way of understanding and explaining how we know what we know (Crotty, 1998), or an attempt to make sense of the possibility, nature, and limits of human intellectual achievement by illuminating the difference between knowledge and opinion in an understanding of what it really to know or really to believe reasonable" (Pollock & Cruz, 1999). It is about what constitutes acceptable knowledge in a particular field of study (Saunders *et al.*, 2015). It is concerned with what we accept as valid knowledge (Collis & Hussey, 2014). Epistemology also concerns the questions of what is (or should be) regarded as acceptable knowledge in a discipline (Bryman, 2004). Collis and Hussey (2014) and Saunders *et al.* (2012) define two positions for epistemology; the positivism, and interpretivism, while Easterby-Smith *et al.* (2012) point to these two positions as 'Positivism' and 'Social Constructionism'.

**Positivism** is defined by Bryman (2004) as "an epistemological position that advocates the application of methods of the natural sciences to the study of social reality and beyond". The key idea of positivism is that the social world exists externally, and that its properties should be measured through objective methods rather than being inferred subjectively through sensation, reflection or intuition (Easterby-Smith *et al.*, 2012). The positivist research is undertaken in a value-free way (Saunders *et al.*, 2012).

**Social Constructionism (interpretivism)**: this theoretical perspective was developed in response to the recognition that natural world sciences and social science are two different worlds (Crotty, 1998). It attempts to minimise the distance between the researcher and what is being researched (Collis & Hussey, 2014). The idea of social constructionism focuses on the ways that people make sense of the world especially through sharing their experiences with others via the medium of language. It is the idea that 'reality' is determined by people rather than by objective and external

factors (Easterby-Smith *et al.*, 2012). The methods of social constructionism research can be contrasted directly with eight features of classical positive research as summarised in

Table 4.2.

Table 4.2: Contrasting implications of positivism and social constructionism

	<b>Positivism</b>	<b>Social Constructionism</b>
The observer	must be independent	is part of what is being observed
Human interests	should be irrelevant	are the main driver of the science
Explanations	must demonstrate causality	aim to increase the general understanding of the situation
Research progress through	hypotheses and deduction	gathering rich data from which ideas are induced
Concepts	need to be defined so that they can be measured	should incorporate stakeholder perspectives
Units of analysis	should be reduced to the simplest terms	may include the complexity of the 'whole' situation
Generalisation through	statistical probability	theoretical abstraction
Sampling requires	large numbers selected randomly	small numbers of cases chosen for specific reasons

(Source: Easterby-Smith *et al.* 2012, p24)

#### 4.4.3 Axiology

Saunders *et al.* (2012) argue axiology refers to the role of values and ethics within the research. It is the process of social enquiry. Heron (1996) argues that our values are the guiding reason of all human action and researchers demonstrate axiological skill by being able to articulate their values. Collis and Hussey (2014) and Remenyi *et al.* (2003) stated that axiology has two aspects which are known as: **value-free** (the choice of what to study and how to study) and **value laden** (researcher is part of the data collection process). When research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance (positivism), and in realism research is value laden; the researcher is biased by world views, cultural experiences and upbringing (Saunders *et al.*, 2012).

#### 4.4.4 Philosophical positioning of the research

This research aims to develop an early warning system guidance for flash flood in the Petra region to enhance resilience. To achieve the research objectives and research questions, the research philosophy is likely to be placed at the end of the extreme continuum of ontology, epistemology and axiology as shown in Figure 4.2.

For the *ontology*, researcher has to identify the aspect of study, where it is objective and exist in reality external to social actors (researchers), or subjective which created from perceptions and consequent actions of the social actors concerned with their existence (Saunders *et al.*, 2012). In this research, it is expected to critically review the current early warning systems related to flooding. In addressing this, the meaning given to early warning system and the way it relates to flash flooding which is highly subjective and socially constructed. Therefore, the intended study would be positioned towards the *subjectivism* aspect of ontology because it is about understanding the meanings that individuals attach to social phenomena, and its necessary to explore the subjective meaning motivating the actions actors take in order for the researcher to be able to understand these actions (Saunders *et al.*, 2012).

From an *epistemological* point of view, the dynamics of this research is underpinned by influencing community preparedness and collaborative actions with the local Government stakeholders within the Petra Region to explore and evaluate a flash flood early warning system. Research focuses at the knowledge, thoughts, and feelings about the impacts of these flash floods, and what do they propose to reduce the impacts of flash floods. Therefore, researcher needs to be embedded in this study to understand and explain disaster. Hence, the epistemology assumption lies on the *social constructivism* (interpretivism). The study will investigate the potential, scientific and practical benefit of the system in the area. The Conceptual framework constructed in figure 3.1 will be tested and validated through validation of collected data.

For *axiology*, while researcher is part of the data collection process and will conduct a study where researcher places great importance on data collected through interview, and research involves people perception, which is subjective and biased, then the axiological assumption position is on the *value laden*.

As shown in figure 4.2, the research is positioned at the end of the extreme continuum because:

- Research is positioned towards the *subjectivism* aspect of ontology, because it is understanding the meanings that individuals attach to social phenomena, and its necessary to explore the subjective meaning motivating the actions actors in order for the researcher to be able to understand these actions.
- Research focuses at the knowledge, thoughts, and feelings about the impacts of these flash floods, and what do they propose to reduce the impacts of flash floods. Therefore, researcher needs to be embedded in this study to understand and explain disaster. Hence, the epistemology assumption lies on the social constructivism (interpretivism).



- While researcher is part of the data collection process and will conduct a study where researcher places great importance on data collected through interview, and research involves people perception, which is subjective and biased, then the axiological assumption position is on the *value laden*.

The data collection techniques involve the collection of qualitative data and deployment of semi-structured interview with small samples and in-depth investigations.

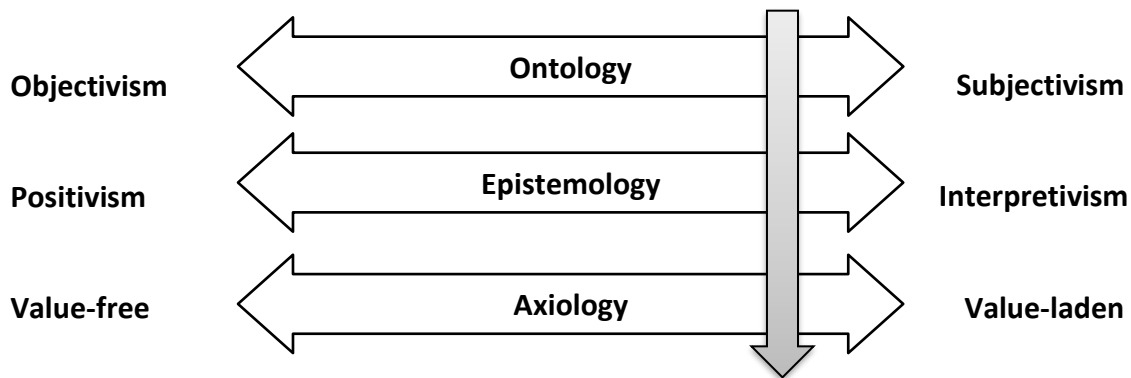


Figure 4.2: Philosophical positioning of the research

Furthermore, Saunders *et al.* (2012) categorised the philosophical continuum into four categories: positivism, realism, interpretivism, and pragmatism. The characteristics of each of these four categories based on its philosophical assumptions are presented in Table 4.3. In terms of classifications method, this research can be classified as tending towards the interpretivism approach.

Table 4.3: Comparison of four research philosophies in management research

	Positivism	Realism	Interpretivism	Pragmatism
Ontology: <i>the researcher's view of the nature of reality or being</i>	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question

Epistemology: <i>the researcher's view regarding what constitutes acceptable knowledge</i>	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, Reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: <i>the researcher's view of the role of values in research</i>	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in- depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

(Source: Saunders *et al.*, 2009)

## 4.5 Research approach

The research approach is the approach taken towards the data collection and analysis, which is classified as the deductive approach or the inductive approach (Saunders et al., 2012). Ketokivi and Mantere (2010) stated that the deductive and inductive approaches are based upon the reasoning that researcher adopts. They added that there is also a third form of reasoning; abductive reasoning, that is just as common in research. Saunders and his colleagues added that deduction owes more to positivism and induction more to interpretivism.

### 4.5.1 Deductive

According to Saunders et al. (2012) deductive approach (testing theory) is where a theory and hypothesis (or hypotheses) are developed and then a research strategy is designed to test the hypothesis (see figure 4.3). The theory would follow the data rather than vice versa. Ketokivi and

Mantere (2010) stated that deductive reasoning occurs when the conclusion is derived logically from a set of premises, the conclusion being true when all the premises are true. Collis and Hussey (2009) stated that deductive is a study in which a conceptual and theoretical structure is developed and the tested by empirical observation; thus, particular instances are deduced from general inferences. For this reason, the deductive method is referred to as moving from the general to the particular. Building in the Ketokivi and Mantere deductive reasoning, if research starts with theory, often developed from reading of the academic literature, and a research strategy is designed to test the theory, a deductive approach is being used.

#### **4.5.2 Inductive**

According to Saunders *et al.* (2012) inductive approach (building theory) is where the data is collected and a theory developed as a result of data analysis (see figure 4.3). The data would follow the theory. Ketokivi and Mantere (2010) stated that in inductive reasoning, there is a gap in the logic argument between the conclusion and the premises observed, the conclusion being 'judged' to be supported by the observations made. Collis and Hussey (2009) stated that inductive research is a study in which theory is developed from the observation of empirical reality; thus, general inferences are induced from particular instances, which is reverse of the deductive method. Since it involves moving from individual observation to statements of general patterns or laws, it is referred to as moving from the specific to the general. Building on the Ketokivi and Mantere ontology, if research starts by collecting data to explore a phenomenon and theory was generated or built (often in the form of a conceptual framework) then an inductive approach is being used.

#### **4.5.3 Abductive**

Instead of moving from theory to data (as in deduction) or data to theory (as in induction) an abductive approach moves back and forth, in effect combines both the deduction and induction approach (see figure 4.3) (Suddaby, 2006). Abductive begins with the observation of a 'surprising fact'; it then works out a plausible theory of how this could have occurred (Saunders et al., 2012). There is also a third form of reasoning that is just as common in research, abductive reasoning, which begins with a 'surprising fact' being observed (Ketokivi & Mantere, 2010). Ketokivi and Mantere added that where researcher is collecting data to explore a phenomenon, identifies themes and explains patterns to generate a new or modify an existing theory which researcher subsequently tests through additional data collection then researcher is using abductive approach (Ketokivi & Mantere, 2010). The deduction, induction and abduction approaches are further discussed in table 4.4 as a comparison from reason to research.

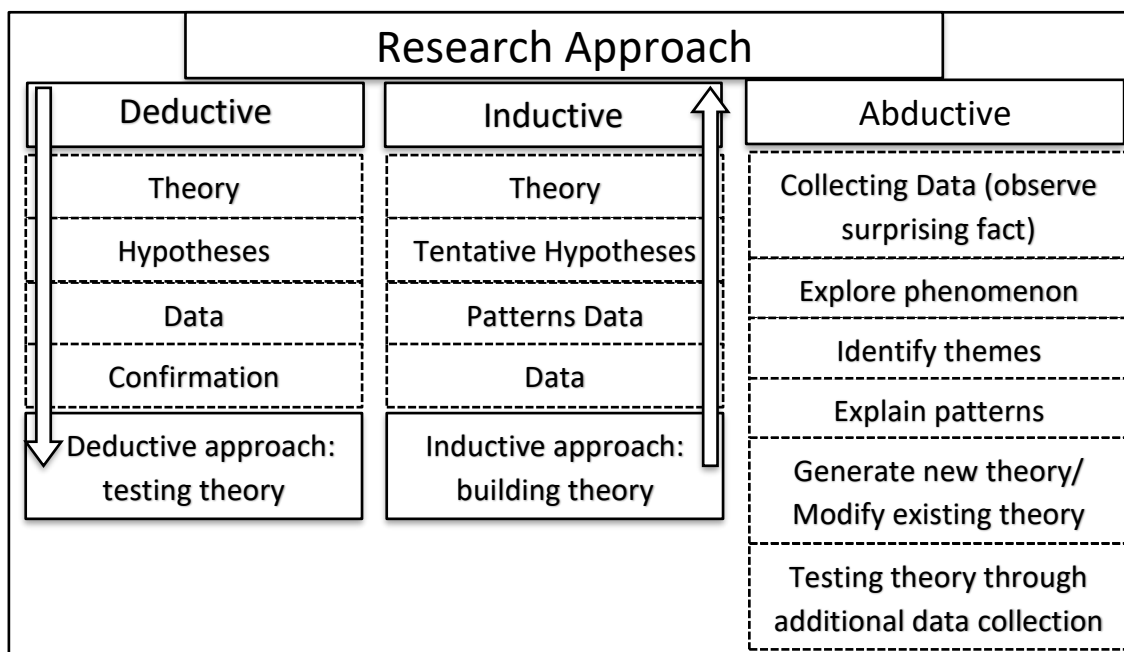


Figure 4.3: Research Approach

Source: Adopted from Saunders et al. (2012)

Table 4.4: Deduction, induction and abduction: from reason to research

	Deduction	Induction	Abduction
<b>Logic</b>	In a deductive inference, when the premises are true, the conclusion must also be true	In an inductive inference, known premises are used to generate untested conclusions	In an abductive inference, known premises are used to generate testable conclusions
<b>Generalisability</b>	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
<b>Use of data</b>	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth
<b>Theory</b>	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory where appropriate, to build new theory or modify existing theory

Source: (Saunders *et al.* (2012, P. 144)

The philosophical assumptions of the research led the researcher to implement both inductive and deductive approaches to accomplish research's aim and objectives. At the first phase, researcher starts with theory which developed by reviewing the academic literature of the flash flood events and their impacts in the study area and examining the specific factors that contribute to flash flood events and their impacts in study area. In this phase, researcher moves from general level to specific level (deductive).

In the subsequent phase, the researcher (i) collects relevant data through conducting interviews with selective groups to review the incident reports of previous flash floods events and their effects in the study area (ii) explores the flash flood phenomena of the flash floods in the study area (iii) analyses data looking for patterns; these patterns might be the intensity, frequency, occurrence time, or occurrence place, and; (iv) develops a theory (conceptual framework) to find an explanation for those patterns. Therefore, researcher will move from data to theory or from the specific to general (inductive).

#### **4.6 Methodological Choice**

Saunders *et al.* (2012) stated that methodological choices have two main approaches known as: (I) mono method (quantitative, qualitative), and (II) multiple methods which also are divided into two sub-approaches: multimethod (multimethod-quantitative, multimethod-qualitative), and mixed methods (mixed model, mixed method).

**Quantitative** research concerns with numerical data (numbers) whereas qualitative research concerns with non-numeric (words, images, video clips and other similar material). In this way, 'quantitative' is often used as a synonym for any data collection techniques (such as questionnaire) or data analysis procedure (such as graphs or statistics) that generates or uses numerical data. In contrast, 'qualitative' is often used as synonym for any data collection technique (such as interview) or data analysis procedure (such as categorising) that generates or uses non-numerical data. In other words, qualitative concerns with understanding things rather than measuring them (Saunders *et al.*, 2015).

**Qualitative** research is conducted through an intense and/or prolonged contact with a "field" or life situation. These situations are typically "banal" or normal, reflective of everyday life individuals, groups, societies and organisations (Miles & Huberman, 1994, cited in Amaratunga *et al.*, 2002). Qualitative research is associated with an interpretive philosophy (Denzin & Lincoln, 2005). Amaratunga *et al.* (2002) argue that perhaps as a response to the dominance of quantitative

research, some qualitative researchers such as (King, 1994) seem to assume a fixed preference or predefined evaluation of what is good and bad research methodology. Such normative assumptions have, of course, been around for many years and are illustrated in Table 4.5.

Table 4.5: Claimed features of qualitative and quantitative methods

Quantitative	Qualitative
<ul style="list-style-type: none"> <li>• Inquiry from the outside</li> <li>• Underpinned by a completely different set of epistemological foundations from those in qualitative research</li> <li>• Are simply different ways to the same end?</li> <li>• Involves the following of various states of the scientific research</li> <li>• The results are said to be hard generalisable data</li> </ul>	<ul style="list-style-type: none"> <li>• Inquiry from the inside</li> <li>• An attempt to take account of differences between people</li> <li>• Aimed at flexibility and lack of structure, in order to allow theory and concepts to proceed in tandem</li> <li>• The results are said to be, through theoretical generalisation, “deep, rich and meaningful”</li> <li>• Inductive - where propositions may develop not only from practice, or literature review, but also from ideas themselves</li> <li>• An approach to the study of the social world, which seeks to describe and analyse the culture and behaviour of humans and their groups from the point of view of those being studied</li> </ul>

Source: Amaratunga et al (2002)

Based on the constructionism epistemological undertaking and the theoretical perspective of being interpretivism in nature, this research would fall under the category of qualitative research. This research seeks to collect the data about flash flood impacts on the study area from literature and interviewing people to take their opinions, thoughts, and suggestions to develop a tool to mitigate flash flood impacts. These propositions will develop through literature review and interviewees’ ideas. Moreover, the researcher will seek to describe and analyse the culture and behaviour of the people in the study area. Based on these reasons and the philosophical stance of the research, qualitative method is best suited for this study. The qualitative research normally emphasises the meaning rather than quantification in collecting data and analysis of data (Bryman et al, 2003). Thus, the research would lead to generation of a theory as the outcome of the research.

#### 4.7 Research strategies

Saunders *et al.* (2012) defined research strategy as ‘a plan of how a researcher will go about answering the research questions’. It is based on the ontological assumptions, epistemological

undertakings and axiological purposes. It is the methodological link between your philosophy and subsequent choice of methods to collect and analyse data (Denzin and Kincoln 2005). There are often open boundaries between research philosophies, research approaches and research strategies, in a similar way, a particular research strategy should not be seen as inherently superior or inferior to any other. In addition, the most important is whether it will enable researcher to answer research question(s) and meet research objectives (Saunders *et al.*, 2012). It must be remembered that these strategies should not be thought of as mutually exclusive (Saunders *et al.*, 2012; Yin, 2009). Each strategy can be used for exploratory, descriptive and explanatory research (Yin, 2003), however, some of strategies belong to the deductive approach, others to the inductive approach (Saunders *et al.*, 2012).

Easterby-Smith *et al.* (2008) and Saunders *et al.* (2012) classified research strategies as experiment, survey, case study, action research, ethnography, archival research, grounded theory, and narrative inquiry, whilst Yin (2014) classified them as experiment, survey, archival analysis, history and case study, which he called research methods. Saunders *et al.* (2012) mentioned that the experiment and survey are principally or exclusively linked to quantitative research design. Case study and action research may involve quantitative or qualitative research, or a mixed design combining both. The ethnography, archival research, grounded theory, and narrative inquiry strategies are principally or exclusively linked to qualitative research design (Saunders *et al.*, 2012).

Qualitative research is associated with a variety of strategies. Whilst these share ontological and epistemological roots and common characteristics, each strategy has a specific emphasis and scope as well as a particular set of procedures.

The selection of the research strategy is based on three conditions: (a) the type of research, (b) the extent of control an investigator has over actual behavioural events, and (c) the degree of focus on contemporary as opposed to historical events (Yin, 2014). Table 4.6 displays these three conditions and shows how each is related to five major research methods.

Table 4.6: Relevant Situations for Different Research Methods

Method	Form of research Question	Requires Control of Behavioural Events?	Focus on Contemporary Events?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival Analysis	Who, what, where, how many, how much?	No	Yes/no
History	How, why?	No	No

Case Study	How, why?	No	Yes
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Reprinted from (Yin, 2014)

According to Yin (2014) the importance of each condition, in distinguishing among the five major research methods, is as follows:

- (a) *Types of research questions*: The first and most important condition for differentiating among the various research methods is to classify the type of research question being asked. In general, “what” questions may either be exploratory (in which case, any of the methods could be used) or about prevalence (in which surveys or the analysis of archival records would be favoured). “how” and “why” questions are likely to favour using a case study, experiment, or history, this where this study takes place.
- (b) *Extent of control over behavioural events* and (c) *degree of focus on contemporary as opposed to entirely historical events*: As “what”, which is a form of “why”, “how” questions are the focus of this research, these two remaining conditions help to distinguish further among a history, case study, and experiment.

A history is preferred method when dealing with the “dead” past, when direct observation is not possible and when no relevant persons are a live to report (Yin, 2014). However, observations for flash floods are possible which are quite often happening every year, and the relevant persons are alive to report about flash flood events and their impact in the study area. Therefore; history is not the suitable research strategy for this study.

Experiments are done when an investigator can manipulate behaviour directly, precisely, and systematically. This can occur in a laboratory setting, in which experiment may focus on one or two isolated variables, or it can be done in a field setting, where investigators “treat” whole groups of people in different ways (Yin, 2014). In this research, the researcher will conduct interviews with two groups; experts and users for flash flood, in where researcher treat both groups of people in same way. Therefore, experiment is not suitable for this research as well.

Case study is preferred when examining contemporary events, but when the relevant behaviours cannot be manipulated. It relies on two sources of evidence: direct observation of the events being studied and interviews of the people involved in the events (Yin, 2014). In this research, researcher examines flash floods as contemporary phenomena, in which researcher will collect the observation of the flash flood events through interviewing involved people in the study area to review their observations, knowledge, facts, experiences.



For further justification, it is worth illustrating the reason for excluding of the other research strategies. Taking into consideration the research philosophical continuum and factors proposed by Yin (2014), ethnography, action research, grounded theory and narrative inquiry are clearly not suitable for this research. Ethnography is used to study people in groups, who interact with one another and share the same space (Saunders *et al.*, 2012). This study does not intend to study people in groups, who interact with one another and share same space.

Action Research is an emergent and iterative process of inquiry that is designed to develop solutions to real organisational problems through a participative and collaborative approach, which uses different forms of knowledge, and will have implications for participants and the organisation beyond the research project (Coghlan & Brannick, 2010; Reason, 2006; Reason & Bradbury, 2008; Shani & Pasmore, 1985). Action research is more appropriate for medium- or long-term research projects rather than short-term ones (Saunders *et al.*, 2009, 2012, 2015). Since the research here is not emergent or iterative process of inquiry to develop solutions to real organisational problems, it will not have any implications on the participants or study area, and the research is not medium - or long-term research, therefore action research will not be a suitable strategy for this research. On the contrary, this research will be of great benefit to the study area and its inhabitants by reducing the risk of flash floods and their effects.

Grounded theory (GT) is about generating or discovering a theory (Glaser & Strauss, 1967). Glaser (1992) further stated that the general methodology of analysis linked with data collection that uses a systematically applied set of methods to generate an inductive theory about a substantive area (Glaser, 1992). It is used to develop theoretical explanations of social interactions and processes in a wide range of contexts including business and management (Saunders *et al.*, 2012). GT uses coding to reorganise data into categories (**open coding**), recognising relationships between categories (**axial coding**), and integrating the categories to produce a theory (**selective coding**) (Strauss & Corbin, 1998). Each item of data collected is compared with one another as well as against the codes being used to categorise the data (Saunders *et al.*, 2012).

A narrative inquiry is a story; a personal account interpreting an event or sequence of events. It seeks to preserve chronological connections and the sequencing of events as told by the narrator (participant), to enrich understanding and aid analysis (Saunders *et al.*, 2012). Whereas in this research, it is about reviewing events, their impacts, the early warning systems used in the study area and collecting these data to build theory that leads to developing the early warning systems

guidance for flash floods. Chase (2005) argues that this strategy provides the opportunity to connect events and actions over time into a 'meaningful whole'.

Yin (2014) stated that researcher should be able to identify some situations in which all research methods might be relevant and other situations in which two methods might be considered equally attractive. Researcher also can use multiple methods in any given study (for example, a survey within a case study or a case study within a survey). To this extent, the various methods are not mutually exclusive but researcher should be able to identify some situations in which specific methods has a distinct advantage. For the case study research, this niche is when:

- A “how” or “why” question is being asked about;
- A contemporary set of events; and
- Over which a researcher has little or no control.

This research reported here was to develop and answer question of;

1. How do flash flooding events affect countries in the world in general?
2. How did flash flood events affect Petra Region in Particular?
3. What are the best practices adopted by countries prone to floods to mitigate the impacts?
4. How can guidance of a responsive EWS for flash floods be developed? What are the empirical elements of the guidance within early warning system for flash flood?

The research questions are predominantly consisting of how and why type of research questions, favouring a case study research. The second condition identified by Yin (2014), is the degree of control of the researcher has over behavioural events. The researcher did not have control over the behaviour of the flash floods or their impacts. The researcher is outside the “case” and will be an observer. The researcher examines flash floods as contemporary phenomena, in which researcher will collect the observation of the flash flood events through interviewing involved people in the study area to review their observations, knowledge, facts, experiences

This section has justified the rationale behind the researcher’s choice of case study as the most appropriate strategy for this research. The next section describes case study in more details and the detailed design of the case study strategy.

#### **4.7.1 Case study**

According to Yin (2014, p. 16), a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context, especially when the boundaries between

phenomenon and context may not be clearly evident. In other words, researcher would want to use the case study research to understand a real-world case and assume that such understanding is likely to involve important contextual conditions pertinent to phenomenon of study (Yin & Davis, 2007). This part covers the scope of a case study, and helps researcher to continue distinguishing case study research from the other methods (Yin, 2014), whilst the second part covers the technical features of a case study, and admits that the phenomenon and context are not always sharply distinguishable in the real-world situation. The technical features of a case study included in Yin's definition are: case study inquiry copes with the technically distinctive situation; relies on multiple sources of evidence; and benefits from prior development of theoretical prepositions to guide data collection and analysis (Yin, 2014, p. 17).

In essence, the twofold definition shows how case study research comprises an all covering the logic of design, data collection techniques, and specific approaches to data analysis. Therefore, case study research is not limited to being a data collection method alone or even a design feature alone (Stoecker, 1991). As related, but important not, case study research is not just a form of qualitative research, even though some have recognised the case study as being among the array of qualitative research choices (e.g., Creswell, 2012).

Therefore, it can be seen that case study is capable of accommodating different research techniques. Moreover, case study may use quantitative, qualitative methods or may use mixed methods approach. It provides the opportunity of dealing with a full variety of data collection such as interviews, observation, documentary analysis and questionnaires (Yin, 2009). Yin (2014) further identified five components of the research design for case studies; case study's questions, its propositions if any, its unit(s) of analysis, the logic linking the data to the propositions, and the criteria for interpreting the findings. Case study research leads to development of new insights that would not have emerged through a large survey (Chetty, 1996). This research concentrates on understanding and reviewing the current flood risk management being adapted in the study area, particularly the modelling methods and EWS's related to flooding, and how the current EWS's principles integrate with the nature of flash flooding in the study area.

The case study strategy will be more relevant when the researcher wishes to gain a rich understanding of the context of the research and the processes being enacted (Eisenhardt & Graebner, 2007). This research consists of a mix of 'what' and 'how' questions, for this reason, the case study strategy is most often used in explanatory and exploratory research (Saunders *et al.*, 2012). The study also focuses on a contemporary event where existing background knowledge is

present to develop an initial framework for flash flood EWS which justified the selection of the case study research strategy. On the other hand, the case study has a unique strength to deal with a full variety of evidence-documents, artefacts, interviews and observations, and still have an impact on the selection (Yin, 2009). In this research, researcher will use a (i) face-to-face interview and (ii) documentary analysis to collect data that is relevant to study area.

Tharenou *et al.* (2007) summarized case study as an in-depth investigation of a single instance. Cases are suitable for explaining complex situations and provided an explanation of processes of a phenomenon in context. Case studies are used specially to understand social processes in their organisational and environmental context, which could be contemporary and/or historical.

#### 4.7.2 Case study design

Yin (2009) distinguishes between four case study strategies based upon two discrete dimensions: single case versus multiple cases, and holistic case (single unit of analysis) versus embedded case (multiple unit of analysis). Four types of designs will be discussed, based on a  $2 \times 2$  matrix (see **Error! Reference source not found.**).

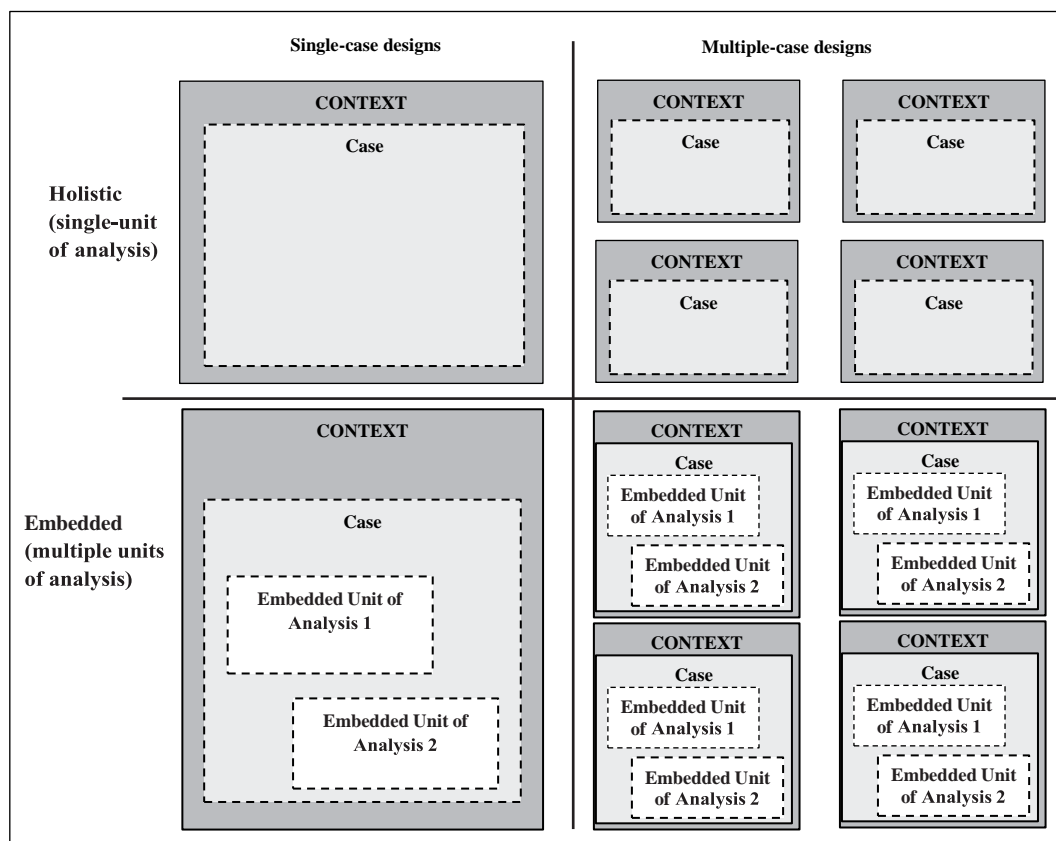


Figure 4.4: Basic Types of Designs for Case Studies

Source: (Yin, 2014, P. 50)

The matrix in **Error! Reference source not found.** first shows that every type of design will include the desire to analyse contextual conditions in relation to the “case,” with the dotted lines between the two signalling that the boundaries between the case and the context are not likely to be sharp. The matrix then shows that single- and multiple-case studies reflect different design situations and that, within these two variants, there also can be unitary or multiple units of analysis. The resulting four types of designs for case studies are (Type 1) single-case (holistic) designs, (Type 2) single-case (embedded) designs, (Type 3) multiple-case (holistic) designs, and (Type 4) multiple-case (embedded) designs (Yin, 2014).

#### 4.7.2.1 Single case

It is often used where it represents a critical case or, alternatively, an extreme or unique case. Conversely, a single case may be selected because it is typical or because it provides researcher with an opportunity to observe and analyse a phenomenon that few have considered before. Inevitably, an important aspect of using a single case is defining the actual case (Saunders *et al.*, 2012). Yin (2009) determines five rationales for using single case study; (I) when it represents the *critical case* in testing a well-formulated theory, (II) where the case represents an *extreme case* or a *unique case*, (III) case study is the *representative* or *typical* case, and (IV) the *revelatory* case. This situation exists when an investigator has an opportunity to observe and analyse a phenomenon previously inaccessible to social science inquiry, and (V) *longitudinal* case: studying the same single case at two or more different points in time.

The same Single case study may involve more than one unit of analysis. This occurs when, within a single case, attention is also given to a subunit or subunits. (McClintock, 1985). The resulting design would be called an embedded case study design. In this contrast, if the case study examined only the global nature of an organization, a holistic design would have been used (Yin, 2014).

The rationale for using a single case study in this research is to represent a critical case such as Petra Region, which is threatened by flash floods that cause wide damages in the region. The Petra region is a unique case because of the archaeological site that is exposed to flooding and has a ramification on the tourist activities. A representative case can be a pilot case in the region or the whole world.

#### 4.7.2.2 Multiple Cases

Research study uses a multiple case design when study contains more than a single case (see **Error! Reference source not found.**) (Yin, 2014). The rationale for using multiple cases focuses on whether findings can be replicated across cases. Cases will be carefully chosen on the basis that similar results are predicted to be produced from each one (Saunders *et al.*, 2012). However, any use of multiple-

case designs should follow a replication, not a sampling logic, and an investigator must choose each case carefully (Yin, 2014). Yin added that the individual cases within a multiple-case study design may be either holistic or embedded. When an embedded design is used, each individual case study may in fact include the collection and analysis of quantitative data, including the use of surveys within each case. The flash flooding phenomenon, which could be considered contemporary and historical issue, has to be studied in a real-life context. It also requires an in-depth study to the flash flood phenomenon and how the EWS could positively contribute to mitigation system and hence, increase area resilience.

According Saunders *et al.* (2009) the classification of research purpose most often used in the research methods' literature is the threefold one of *exploratory*, *descriptive* and *explanatory*. *Exploratory* research is a valuable means of finding out 'what is happening; to seek new insights, to ask questions and to assess phenomena in a new light' (Robson, 2011). The object of *descriptive* research is 'to portray an accurate profile of persons, events or situations', whereas explanatory research aims to establish causal relationships between variables to understand the nature and the causes of the problem (Saunders *et al.*, 2012). Likewise, Yin (2014) notes three categories, namely exploratory, descriptive and explanatory case studies.

First, exploratory case studies set to explore any phenomenon in the data which serves as a point of interest to the researcher. Second, descriptive case studies set to describe the natural phenomena which occur within the data in question. Third, explanatory case studies examine the data closely both at a surface and deep level in order to explain the phenomena in the data (Zainal, 2007). The choices are depending on the research question.

In this research, the case study strategy was chosen to: (i) review the incident reports of the flash floods and their effects in the study area, and (ii) obtain a depth understanding of the information necessary to examine the process of developing EWS for flash floods in Petra Region. Therefore, the most appropriate research strategy as this research consists of 'how' (descriptive) and 'what' (exploratory) types of research questions. Thus, this research moves towards the descriptive and exploratory case study.

#### **4.7.3 Unit of analysis**

Unit of analysis is the phenomenon under the study, about which data are collected and analysed, and closely linked to the research problem and research question (Collis & Hussey, 2009). Yin (2014) states that unit of analysis is related to the fundamental problem of defining the "case" to be

studied. Case can be individuals, groups, organisations, movements, events, or geographic units (Neuman, 2011). In this research, the unit of analysis is flash floods in the Petra Region. It is particularly restricted to Petra because the flash floods disaster risks have become the main subject of attention during every recovery and reconstruction post-flash flood. The audience for this research will be the local communities that are exposed to flash flooding impacts in the study area. This section has described case study in more details and the detailed design of the case study strategy. The next section describes the research techniques and procedure used for data collection and analysis.

#### **4.8 Time Horizon**

The time horizons are employed to analyse whether the researcher wants the research to be a “snapshot” taken at a particular time or researcher wants it to be more akin to a diary or series of snapshots and be a representation of events over a given period. The research onion (see Figure 4.1) showed two principles of the time horizon; the ‘snapshot’ time horizon or ***cross-sectional***, and the ‘diary’ perspective or ***longitudinal*** (Saunders *et al.*, 2012). In the cross-sectional studies, the researcher often studies one particular phenomenon at a particular time, whereas in longitudinal studies, the researcher studies the changes of phenomenon over a given period.

This study does not intend to examine the phenomenon of flash flood over a period of time, or compare impacts changes from particular time to another. Therefore, the work reported in this thesis reflected the cross-sectional studies with small sample because all variables studies are considered at the same specific point of time.

#### **4.9 Research Techniques and procedure**

This section discusses the techniques and procedure used for data collection and analysis. As the qualitative research choice was selected for the study, qualitative data collection was used. The research techniques used for data collection and analysis are briefly outlined in this section. Figure 4.5 shows the overall research process of this doctoral study and the different data collection techniques used. This research study initially consists of the data techniques of case study including semi-structured interview and documents.

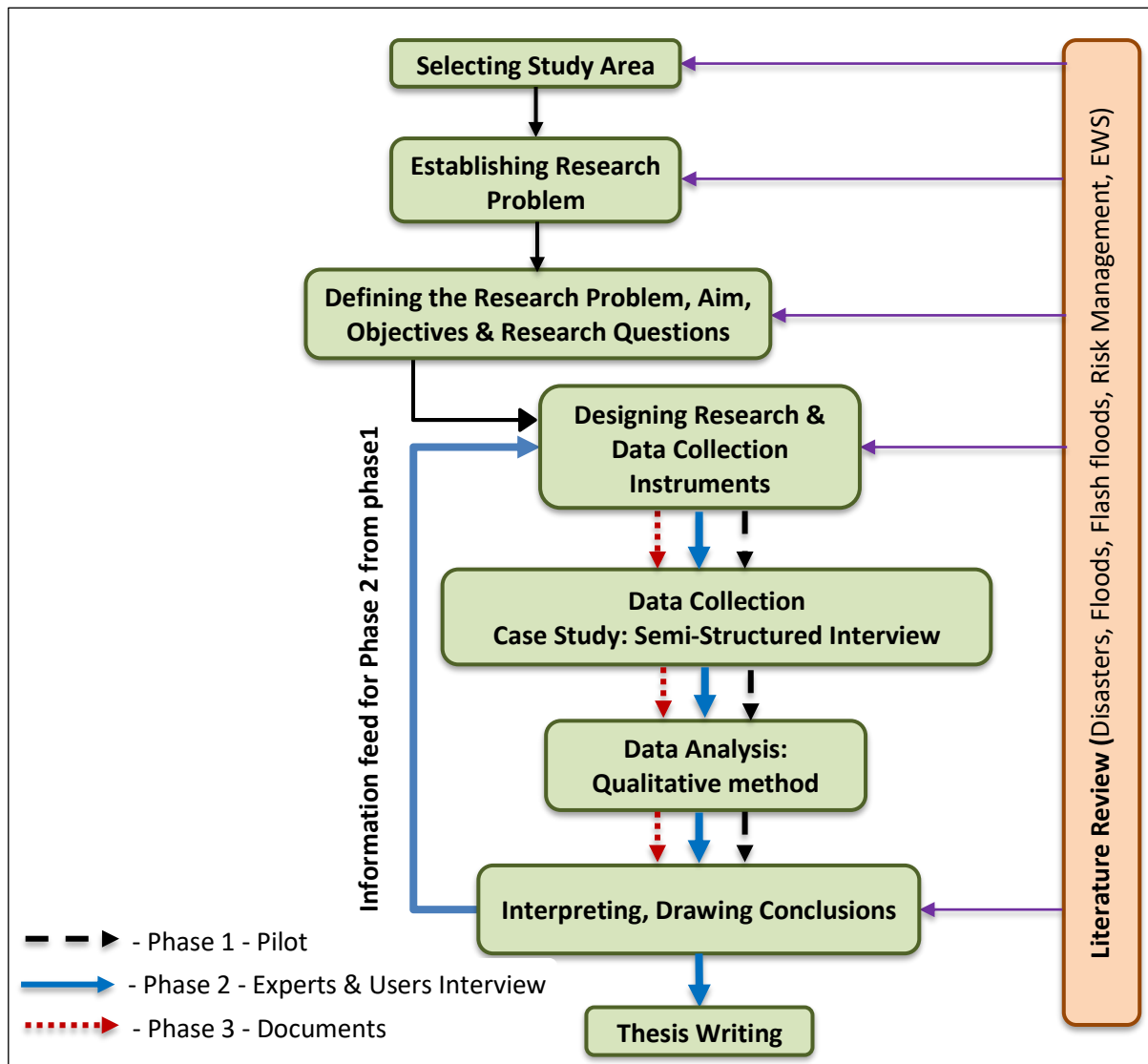


Figure 4.5: Research process of the study

Source: Adopted from (Nirooja, 2013)

#### 4.9.1 Triangulation

Most research questions are answered using some combination of secondary and primary data (Saunders *et al.*, 2012). Therefore, it can be summarised that the sources of data collection for this research are primary and secondary data. Bryman (2012) defined primary data as the information gathered directly from people, and directly analysed and managed by a researcher or research team, or data that are collected for specific research problem at hand, using procedures that fit the research problem best (Hox & Boeije, 2005). It consists of information from interview, questionnaire, experiment, observation, etc.

Secondary data are data which have been documented and written and can be used for reference purpose only (Trochim & Donnelly, 2006). It consists of data from textbooks, reports, newspapers,



documentary, survey, etc. The process of combining source evidence of data and analysis of this data is called triangulation (Trochim & Donnelly, 2006).

Bryman (2008, p. 700) defined triangulation as 'the use of more than one method or source of data in the study of a phenomenon so that findings may be cross-checked'. It refers 'to the use of more than one source of data and more than one theory to support the arguments and conclusions. More than one investigator may be used to collect the data to make findings more reliable' (Babbie & Mouton, 2002, p. 275), or it refers to the use of two or more independent sources of data or data-collection methods within one study (Saunders *et al.*, 2015). Researcher will primarily focus on three categories, i.e. literature review, documents and interviews.

#### **4.9.2 Data collection**

Petra region has been selected as a case study for this research, which is in high need of preparedness and mitigation measures to reduce flash flood disaster risk. For this reason, this research is intended to use one case study within Petra region, which has badly been affected by flash flood disasters and is prone to future disasters.

Yin (2014) identifies six sources of evidence that can be collected during case studies. Documentation, archival records, interviews, direct observations, participant-observation, and physical artefacts. In this research, data collection techniques will use a combination of different techniques, which might include interviews with managers, expert, local community, tourist sectors, and documentation that will be collected about the past flash flood events (Saunders *et al.*, 2012).

Yin (2014) states that when conducting a case study, four principles of data collection can maximize the benefits of the above six sources of evidence: (a) using multiple, not just single, sources of evidence, documents and interviews were used as sources of evidence; (b) creating a case study database, data categorized under different themes and stored in computer and external disks; (c) maintaining a chain of evidence to increase the reliability of the information; and (d) exercising care in using data from electronic sources of evidence, such as social media communications. Accordingly, this research attempted to employ the interview and documentary as sources of evidence to collect data for qualitative analysis. These two principles combined with literature review evidence will enable data triangulation. This research will use documentary analysis as secondary data source and interviews as primary data source.

#### **4.9.2.1 Sampling**

Sampling techniques enable researcher to reduce the amount of data that researcher needs to collect (Saunders *et al.*, 2015). When selecting a sample, it should represent the full set of cases in a way that is meaningful and could be justified (Becker, 1998). Sampling provides a valid alternative to census when: It would be impracticable for researcher to collect data from entire population and when researcher budget and time constraints prevent him/her from collecting data from the entire population (Saunders *et al.*, 2012).

Sampling techniques are divided to two types: probability sampling and non-probability sampling (Denscombe, 2014; Easterby-Smith *et al.*, 2012; Saunders *et al.*, 2012, 2015). Probability sampling relies on the use of random selection from the research population and it is based on statistical theory relating to the 'normal distribution' of events. It works best with large numbers and it tends to be associated with large-scale surveys using quantitative data. Whilst, non-probability sampling involves an element of discretion or choice on the part of the researcher at some point in the selection process and it is used when researchers find it difficult or undesirable to rely on random selection to the sample, (Denscombe, 2014).

This research reviews the flash flood impacts on the study area which requires specific participants whom have knowledge and experience related to research objectives. Therefore, non-probability sampling is the most suitable sampling techniques to accomplish the research objectives. According to (Denscombe, 2014; Saunders *et al.*, 2015) non-probability sampling has four types: quota, purposive, volunteer and haphazard (see

Table 4.7).

##### **4.9.2.1.1 Quota**

Quota sampling is entirely non-random and is often used for structured interviews as part of a survey strategy. It has similar requirements for sample size as probabilistic sampling techniques (Saunders *et al.*, 2012). Quota sampling has particular advantage when it comes to cost-especially when used with face-to-face interviewing (Denscombe, 2014; Saunders *et al.*, 2015). It can be set up very quickly (Saunders *et al.*, 2012, 2015).

#### **4.9.2.1.2 Purposive**

Saunders et al. (2012) stated that with purposive sampling researcher needs to use his judgement to select cases that will best enable him to answer his research question(s) and to meet his research objectives. Purposive sampling operates on the principle that the best information can be acquired through focusing on a relatively small number of instances (Denscombe, 2014). Saunders et al. (2012) stated that it is often used when working with very small samples such as in case study research and when researcher wishes to select cases that are particularly informative.

In this research, researcher needs a way of getting the best information by selecting very small samples of people whom most likely to have the experience or expertise to provide quality information and valuable insights on the research topic to answer research questions and meet research objectives, therefore, the purposive sampling is the best suited for this research.

#### **4.9.2.1.3 Volunteer**

Saunders *et al.* (2012) classified volunteer sampling into two techniques: snowball sampling and self-selection sampling, whilst Denscombe (2014) considered snowball sampling as a separate group and stated that it is used commonly when it is difficult to identify members of the desired population. With snowball sampling the sample emerges through a process of reference from one person to the next. The sample increases in size as each of the participants is asked, in turn, to nominate another participant who might want to participate in the research. Denscombe added that snowball sampling has no sampling frame, which can allow the researcher to identify and contact appropriate participants, and for this reason, it is often used in conjunction with qualitative research based on small-scale exploratory samples.

Self-selection sampling occurs when researcher allows each case, usually individuals, to identify their desire to take part in the research, researcher therefore: publicises his need for cases, either by advertising through appropriate media or by asking them to take part, then collects data from those who respond (Saunders *et al.*, 2012).

#### **4.9.2.1.4 Haphazard**

Haphazard sampling occurs when sample cases are selected without any obvious principles of organisation in relation to your research question, the most common form being convenience sampling which is known as availability sampling. Findings from convenience sampling are often given very little credibility (Saunders *et al.*, 2012).

Table 4.7 illustrates the impact of various factors on the choice of non-probability sampling techniques.

Table 4.7: Sampling techniques and Impact of various factors on choice of non-probability

Group	Technique	Likelihood of sample being representative	Types of research in which useful	Relative costs	Control over sample contents
Quota	Quota	Reasonable to high, although dependent on selection of quota variables	Where costs constrained or data needed very quickly so an alternative to probability sampling needed	Moderately high to reasonable	Specifies quota selection criteria
Purposive	Extreme case	Low	Unusual or special	Reasonable	Specifies selection criteria
	Heterogeneous	Low, although dependent on researcher's choices	Reveal/illuminate key themes	Reasonable	Specifies selection criteria
	Homogeneous	Low	In-depth focus	Reasonable	Specifies selection criteria
	Critical case	Low	Importance	Reasonable	Specifies selection criteria
	Typical case	Low, although dependent on researcher's choices	Illustrative	Reasonable	Specifies selection criteria
	Theoretical	Low	Inform emerging theory	Reasonable	Specifies selection criteria
Volunteer	Snowball	Low, but cases likely to have characteristics desired	Where cases difficult to identify	Reasonable	Selects initial participant
	Self-selection	Low, as cases self-selected	Where access difficult, research exploratory	Reasonable	Offers only general
Haphazard	Convenience	Very low (often lacks credibility)	Ease of access	Low	Haphazard

Source: (Saunders et al. 2012)

#### 4.9.2.2 Semi-Structured Interviews

Interview is the most common source of evidence for data collection techniques in the case study research approach as it can give in-depth understanding on the phenomenon being investigated, they can help researcher to gather valid and reliable data that are relevant to research question (s) and objectives, and are categorized as either: structured interviews; semi-structured interviews; unstructured interviews (in-depth) (Saunders *et al.*, 2012; Yin, 2014) or standardised interviews (structured interviews) and non-standardised interviews (semi-structured and unstructured) (Saunders *et al.*, 2012).

**Structured interviews** use questionnaires based on a predetermined and 'standardised' or identical set of questions and researchers refer to them as interviewer-administered questionnaires (Saunders *et al.*, 2012, p. 374). They added that this interview is called 'quantitative research interviews' because it is used to collect quantifiable data. Whilst **semi-structured** and **in-depth** (unstructured) **interviews** are often referred to as qualitative research interviews (King, 2004). In **semi-structured interviews**, the researcher will have a list of themes and possibly some key questions to be covered. These interviews are very helpful in an exploratory to find out what is happening and understand the context, and in an explanatory studies in order to understand the relationships between variables (Saunders *et al.*, 2012). Moreover, semi-structured research interviews used for an explanatory purpose may be useful in both inductive and deductive approaches because of the intention to explain relationships that exist.

Some of the most common information found within the literature relating to interviews, according to (Creswell, 2003, 2007) includes (a) the preparation for the interview, (b) the constructing effective research questions, and (c) the actual implementation of the interview(s).

In this research, the interviews would be designed to capture the region's practices in flash flood events and to understand the commitment of the local government in mitigating flash flood risks in and making the region more resilient to flash flood disasters and associated problems, besides the current working system in terms of EWS to flash flood.

##### 4.9.2.2.1 Preparation to Interview

McNamara (2009) suggests the importance of the preparation stage in order to maintain an unambiguous focus as to how the interviews will be erected in order to provide maximum benefit to the proposed research study. Researcher has prepared to interview by: (a) selecting the appropriate candidates for interviews depending on the non-probability sampling technique adopted by researcher to collect data from specific participants who have knowledge and

experience related to research objectives (b) implementing a pilot test in which researcher aims to determine if there are flaws, limitation, or other weaknesses within the interview design and will allow to make necessary revisions prior to the implementation of the study (Turner, 2010).

#### **4.9.2.2.2 Constructing Effective Research Questions**

Creating effective research questions for interview process is one of the most crucial components to interview design (Turner, 2010). In this research study, researcher has constructed the research questions as one template, however, after implementing the pilot interview, researcher reconstructed two effective template research questions (Appendix (B) shows Users' template, and Appendix (C) shows Experts' template). Questions were developed according the conceptual framework stages and sub-stages. These questions were formed within themes and sub-themes to collect required data about flash flood events and their impacts, preparedness and mitigation, and early warning systems.

#### **4.9.2.2.3 Implementation of Interviews**

Before interview, Interviewees were contacted by both phone and email by the researcher. The interviewees were also provided with interview materials such as: participant information sheet, invitation letter to participate, and participant consent form, they also provided with a full idea about the research and its objectives, structure of interview, and the ethics of the interview. These were followed by asking every participant to sign the consent form and seeking his permission to record the interview. Researcher will conduct three pilot interviews to check if:

- The questions were completely understood and answered by interviewees with the appropriate answers.
- The questions of interview are suitable for all the interviewees or do not exceed their knowledge.
- The interviewees answers contain a high-level data and explain the phenomena, the answers are exploratory data about the events of flash floods occurred in the study area and their impacts.

After conducting the pilot testing interviews, the above conditions have not been achieved. This led researcher to divide the participants to two groups to accomplish the research question with saturated data; as such, the data would be gathered through semi-structured interviews with two groups of interviewees as following:

- Experts: a group of experts in flash flood field, has a high-level data, and could explain the phenomena of flash flooding. This group includes experts from: (a) top management

participants from the local concerned authorities (b) academic sector (c) United Nation, non-governmental, communities-based agencies (d) independent experts in flood risk management.

- Users: a group of users whom can provide exploratory data about the events of flash floods occurred in the study area and their impacts. This group includes users from: (a) tourist sector (b) community leaders (c) local authorities.

20 participants; 10 participants per group, have taken part in the interview. The interviews were conducted using face-to-face, telephone, or internet interview methods (Table 4.8 shows the type of interview, interviewers, and nature of interview). Moreover, the interviews were recorded, transcribed, translated from Arabic to English and reviewed by the interviewees. Information collected by interviews represents the most important source for this research.

Table 4.8: Interviews, interviewers and Nature of interview

Type of Interview	Interviewers	Nature of Interview
Semi-structured interviews	1. Experts <ul style="list-style-type: none"> <li>• 4 top management in local authorities</li> <li>• 6 Experts from Universities, UN agencies, independent experts</li> </ul>	One-to-one (face to face, Telephone, Internet)
Semi-structured interviews	2. Users <ul style="list-style-type: none"> <li>• 4 Participants from tourist sector</li> <li>• 3 community leaders</li> <li>• 3 Local Authorities</li> </ul>	One-to-one (face-to-face, Telephone, internet)

As mentioned earlier, Interviewees were from different backgrounds, such as tourist sector, community leaders, government official, practitioners, academic, UN agencies, and independent interviewees, who have a variety of experiences. These interviewees are presented in Table 4.9

Table 4.9: Type of interviews, interviewers and Nature of interview conducted

Interviewee Code	Organisation	Type of Interviewee	Job Title	Experience and qualifications
User_01	PDTRA	Official	Head of Local Comm. Initiatives	B.Sc. 11 years
User_02	PDTRA	Official	Director for Environment	B.Sc. 13 years
User_03	Private Sec.	Ordinary community member	Retired	B.Sc. 30 years
User_04	Hotel Owner	Ordinary community member	General Manager	B.Sc. 25 years
User_05	PDTRA	Official	Chief Commissioner	PhD Eng. 30 yrs.

User_06	PDTRA	Official	Environment Commissioner	B.Sc. 35 years
User_07	Local Community	Ordinary community member	Tourist sector	B.Sc. 26 years
User_08	Local Community	Ordinary community member	Tourist sector	M.Sc. 13 years
User_09	Local Community	Ordinary community member	Tourist sector	High School 20 years
User_10	Head of Hotel Owners Agency	Official	Tourist sector	
Expt_01	Alhussein Bin Talal University	Official	Faculty Dean	PhD 22 yrs.
Expt_02	Uni. of Jordan	Official	Head of Eng. Dept.	PhD 32 yrs.
Expt_03	UNISDR	Official		M.S. 21 yrs.
Expt_04	ASEZA	Official	Director of Urban Planning and Studies & head of DRM unit	B.Sc. 23 years
Expt_05	SDC	Official	DRR division	M.S. 18 yrs.
Expt_06	Private Sec.	DRR Expert	Consultant	PhD 28 yrs.
Expt_07	Private Sec.	DRR Expert	Comm. Projects Coordinator	M.S. 17 yrs.
Expt_08	Cool2Adapt	DRR Expert	Uni. Instructor	PhD 26 yrs.
Expt_09	UNDP	DRR Expert	Consultant	PhD 16 yrs.
Expt_10	EMI	Official	DRR Expert	PhD 35 yrs.

#### 4.9.2.2.4 Interpreting Data

The final activity in the interview design process is that of interpreting the data that was gathered during the interview process. During this phase, according to (Creswell, 2003, 2007), researcher must make 'sense' out of what was just uncovered and compile the data into sections or groups of information, also known as themes or codes. As the interviewees were divided into two groups; users and experts; each interview guidelines consist of four themes to be asked. These themes are listed below under the different grouping.

Users' themes are:

- Flash floods events
- Flash floods impacts
- Local community preparedness
- Local authorities' roles

Experts' themes are:

- Flash flood events and impacts
- Preparedness measures in the study area



- Mitigation measures in the study area
- Early warning systems

#### **4.9.2.3 Documentation**

Documentary secondary data are often used in research projects that also collect primary data. Documentary secondary data include text materials such as notices, correspondence, minutes of meetings, reports to stakeholders, diaries, transcripts of speeches and conversations, administrative and public records, and text of web pages. Text data can also include books, journals and magazine articles and newspapers (Saunders *et al.*, 2012). Documentary secondary data also include non-text materials, such as voice and video recordings, pictures, drawings, films and television programmes (Robson, 2011), DVDs and CD-ROMs as well as web pages. These data can be analysed qualitatively and quantitatively, and can be used to help to triangulate findings based on other data, such as text material and primary data collected through interviews or questionnaires (Saunders *et al.*, 2012).

Mason (2002) states that the analysis of the documentary sources is a major method of social research, and one which many qualitative researchers see as meaningful and appropriate in the context of their research strategy. It is used in this research to overcome the potential low reliability of the data produced from interviews. Yin (2014) asserted that a documentation review is one of the most important ways of supporting evidence gather by other methods of data collection. Mason (2002) and Yin (2014) asserted that documents are useful in reducing researcher bias, even though they are not always accurate and may not be lacking in bias. To achieve reliable data, researcher uses documentary evidence as triangulation for the data obtained from interviews.

Related documents used in this research are: documents explaining the systems that have been adopted to reduce flash flooding, United Nations projects, risk analysis and assessment projects, and flash flood Inventory from PDTRA.

The concept triangulation in this study refers to use different types of techniques to collect data within this study. The information collected in this research is verified, and the researcher used this process to confirm that all data is relevant to the research area. Therefore, for this research, literature review was triangulated with documentation of the PDTRA and the collected data from semi-constructed interview of users and experts. The importance of triangulation is also obvious in accomplishing the research objectives and answering research questions.

#### 4.9.2.4 Semi-structured interview for validation

This interview aims to validate and verify the findings of the research if necessary. It is carried out using semi-structured interview aiming to examine if the findings from the qualitative analysis have successfully captured the real phenomena of the investigated topic. Interview questions were categorised under three main themes: flood events and impacts, preparedness and mitigation, and early warning systems. The themes were based on the findings of the semi-structured interview (research objectives). Additionally, the interviews were carried out with four experts on flood risk reduction. The interviewees were selected based on their experiences. The interviewees ought to have experience in the study area location, and have scientific and practical background in flood risk management in the study area. Four interviewees were classified as satisfactory, because most of them showed their approval of the research findings. Details of the interviewees are presented in Table 4.10.

Table 4.10: Data of interviewees in semi-structured interview for validation

Interviewee	Job Function	Years of Experiences
Interviewee 1	NGO	24
Interviewee 2	Academic Sector	23
Interviewee 3	NGO	18
Interviewee 4	Government official	28

#### 4.9.3 Data analysis

Data analysis consists of examining, categorizing, tabulating, testing or otherwise to address the initial propositions of the study (Yin, 2009). Yin (2009) admits that analysing case study evidence is difficult because techniques still have not been well defined. Qualitative data analysis allowing researcher to develop theory from data (Saunders et al, 2009).

Marshall and Rossman (2006) included data analysis as one of the issues that researcher should consider when formulating a proposal to undertake qualitative research. Kvale (1996) added that the process of analysing qualitative data is likely to begin at the same time as researcher collects these data and continues afterwards. Data collected from interviews will be analysed by qualitative data analysis methods such as content analysis and cognitive mapping.

##### 4.9.3.1 Content analysis

Content analysis is a technique used to analyse texts, whether written, spoken or visual, and the analysis can be either quantitative or qualitative to systematically classify words, phrases, sentences and other units of text into a series of meaningful categories (Kalof *et al.*, 2008, p. 105)

The content analysis is one of the methods used to analyse qualitative data, it is a way of systematically converting text to numerical variables for qualitative data analysis (Collis & Hussey, 2003), or a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use (Krippendorff, 2004). Krippendorff recognized that content analysis could take the procedure of word count or thematic, conceptual analysis. However, the word could be of specific topic that may not deliver an accurate reflection of the importance of the topic that is being discussed. In conceptual content analysis, the text is examined to check the existence of a concept, considering terms related to the concept both implicitly and explicitly (Krippendorff, 2004).

In this research, conceptual content analysis is used to make sure that flash flood events and the impacts mentioned in the interviews are picked up in the analysis if they are considered to have relatively higher significance or provide new knowledge. Moreover, the content analysis adopted in this research is qualitative, and the qualitative content analysis forms a major part of the qualitative data analysis. In this research, content analysis is adopted to match the transcribed words from the semi-structured interviews to key themes. Based on the procedure conducted during the content analysis, data from interviews was transcribed electronically into a Microsoft Word Document. Then the context was carefully explored to investigate the key themes.

The contents analysis will be firstly used to analyse data collected from interviews. Qualitative data analysis process will be carried out using computer software such as NVivo.

#### **4.10 Validity and reliability**

Validity and reliability are two terms used in the examination of the quality of the research. Validity and reliability for qualitative research means that data collection can be repeated with the same findings (Yin, 2014). In the next context, validity and reliability will be discussed in details.

##### **4.10.1 Validity**

Validity is “the extent to which measures and research findings provide accurate representation of the things they are supposed to be describing” (Easterby-Smith *et al.*, 2012, p. 347), It is about integrity of the conclusions that are generated from the research (Bryman, 2012). Robson identifies validity as “whether the findings are ‘really’ about what they appear to be about” (Robson, 2011, p. 77). In other words, it concerns the question of whether the research findings accurately reflect the investigated phenomena (Collis & Hussey, 2014).

In terms of creating validity of a research, the process has been viewed differently by qualitative and quantitative researchers (Neuman, 2011). Regardless of the differences, validity is accomplished by following number of verification strategies during the research process. Researchers have constructed different tests regarding validity such as Cook and Johnson (2006), and Neuman (2011). Yin (2014) discussed three different methods (tests) of validity; construct validity, internal validity, and external validity. The next three sub-sections (4.10.1.1, 4.10.1.2, and 4.10.1.3) show validity methods in details, and Table 4.11 lists the three widely used validity tests, definitions, recommendation case study tactics, and the relevant phase of research.

#### **4.10.1.1 Construct validity**

Construct validity concerns identifying correct operational measures for the concepts being studied, and is implemented during data collection process. It could be met by deploying multiple sources of evidence (Yin, 2014). This research deploys multiple data collection method, qualitative approach. According to Yin (2014) the use of multiple sources of evidence; literature review, interview, case study, and document review in this research, is one way of ensuring construct validity. Further, reviewing the interview transcripts by interviewees is a way of ensuring that their views were correctly recorded, as proposed by Yin (2014). Moreover, establishing proper methodology from start to finish of this research study is also a way of instituting the construct validity of a research, which has been accomplished through this chapter.

#### **4.10.1.2 Internal validity**

Internal validity seeks to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships (Yin, 2014). It is applicable for explanatory study. As this research involves the explanatory study, the internal validity is met by ensuring that the research was built using the logic model, and by executing pattern matching and explanation building during the data analysis.

#### **4.10.1.3 External validity**

External validity defining the domain to which a study's findings can be generalised (Yin, 2014). It is conducted during the research design process. In this research, the process from a review of relevant literature and relating findings to literature as well as comparing the findings at different stages of data collection; pilot testing using semi-structured interview, users and experts semi-

structured interview, reviewing documentation and the use of single case study are the way to ensure the external validity can be accomplished.

#### 4.10.2 Reliability

Reliability refers to whether data collection techniques and analytic procedures would produce consistent findings if they were repeated on another occasion or if they were replicated by different researcher (Saunders *et al.*, 2012). It involves determining the operations of a study can be repeated to obtain the same results (Yin, 2014), and concerns whether the results of the study are repeatable (Bryman & Bell, 2011). Yin (2014) recommends use of a case study protocol and case study database to establish reliability. Accordingly; the target of reliability is to minimise the errors and biases during the data collection process (Amaratunga *et al.*, 2002). Therefore, the reliable research can come up with the same findings if implemented by the same procedures. In this research, the reliability is achieved by creating case study protocol, in which the step by step process of the research is explained (see Table 4.11).

Table 4.11 lists the four widely used tests, definitions, recommendation case study tactics, and the relevant phase of research.

Table 4.11: Case study definition, tactics, and relevant phase of research

Tests	Definition	Case study tactics	Relevant phase of research
Construct validity	Correct operational measure for concepts	<ul style="list-style-type: none"> <li>■ Use multiple sources of evidence</li> <li>■ Establish chain of events</li> <li>■ Have key informants review draft case study report</li> </ul>	<ul style="list-style-type: none"> <li>■ Data collection</li> <li>■ Data collection</li> <li>■ Composition</li> </ul>
Internal validity	Establishing a non-spurious causal relationship (only for explanatory)	<ul style="list-style-type: none"> <li>■ Do pattern matching</li> <li>■ Do explanation building</li> <li>■ Address rival explanation</li> <li>■ Use logic models</li> </ul>	<ul style="list-style-type: none"> <li>■ Data collection</li> <li>■ Data collection</li> <li>■ Data collection</li> <li>■ Data collection</li> </ul>
External validity	Establishing the domain for generalization	<ul style="list-style-type: none"> <li>■ Use theory in single case studies</li> <li>■ Use replication logic in multiple case studies</li> </ul>	<ul style="list-style-type: none"> <li>■ Research design</li> <li>■ Research design</li> </ul>
Reliability	Repeatability of operations of the case study	<ul style="list-style-type: none"> <li>■ Use case study protocol</li> <li>■ Develop case study database</li> </ul>	<ul style="list-style-type: none"> <li>■ Data collection</li> <li>■ Data collection</li> </ul>

Reprinted from: (Yin, 2014, P. 45)

#### **4.11 Summary**

This chapter presented the research methodology adopted for this research to address the research aim, objectives, and questions as well as trustworthiness in a research. First, it presented the researcher's enthusiasm to study and develop a guidance for the flash flood early warning system in Petra and the strong incentives led researcher to conduct this study. Followed by the discussion of the research methodological framework that is composed of stages, summarised as conceptualisation, implementation, interpretation and outcomes in section 4.3. For the philosophical assumptions, the research was positioned toward subjectivism aspect of ontology, interpretivism assumption of epistemology, and value-laden as axiological assumption. In sections 4.5 and 4.6, it is discussed why the researcher adopts both inductive and deductive approaches, and the qualitative method as a methodological choice as the most appropriate method to accomplish the aim and objectives of the research. Furthermore, section 4.7 presented the justification after choosing and considering the single case study as the best suited this research as research strategy, and section 4.8 described the time horizon. Finally, section 4.9 discussed the data collection techniques and the justification for choosing semi-structured interview and document as data collection techniques, and section 4.10 discussed the validity and reliability that for this research and listed the four widely used tests that this research followed, the research process can be seen in figure 4.5.

Having established the research methodology in this chapter, the next Chapter 5 includes reviewing and analysing primary data. Consequently, the findings of the semi-structured interview are discussed and analysed in the next chapter.

## Chapter 5 Data Analysis and Results

### 5.1 Introduction

The literature on key issues relevant to this study was reviewed in Chapter 2. This was followed by establishing the research conceptual framework of the study in Chapter 3. Having established why and how the research is conducted, this chapter seeks to present, discuss and analyse the outcomes of the study, observed through the qualitative research method adopted. Accordingly, the chapter is presented in four parts:

- *Part 1*: introduces the case study, the geography and demography of the flash flood affected area, the impact and the method adopted for reducing flash flood risk.
- *Part 2*: presents the qualitative analysis of the interview data and documents.
- *Part 3*: presents the findings of the data analysis.
- *Part 4*: presents the validation of the data analysis findings.

### Part 1: Case Study

### 5.2 Jordan

#### 5.2.1 Demographic, Economic, Social and Cultural Characteristics

The Hashemite Kingdom of Jordan is a small country in the northern part of the Arabian Peninsula. It is bordered by Syria to the north, Iraq to the north-east, Palestine to the west, and Saudi Arabia to the east and south (see figure 5.1). Jordan shares control of the Dead Sea with Palestine, and the coastline of the Gulf of Aqaba with Palestine, Saudi Arabia, and Egypt. The country lies between 29° and 34° N, and 34° and 40° E. The area of Jordan is 89,213 km<sup>2</sup>; of which 88,884 km<sup>2</sup> are land and 329 km<sup>2</sup> are water (McColl, 2014).

Jordan is a modern Arab nation with a predominately middle class population. The latest census, taken in 2015, showed the population is approximately 9.5 million, while the number of non-Jordanians who reside in the country is around 2.9 million, representing 30.6 % of overall population. The vast majority of Jordanian are Arabs, accounting for 98% of the population (Ghazal, 2016). Most Jordan's population of 9.5 million live in urban areas; mainly Amman, Zarqa, and Irbid. The country is divided into 3 regions made up of 12 governorates, Irbid, Jarash, Ajloun and Mafrq are in the Northern region, Amman, Zarqa, Balqa and Madaba are in the Central Region, and Karak, Taffileh, Ma'an and Aqaba southern region (see Figure 5.1). According to the World Bank, population growth (annual %) in Jordan was last measured at 2.38% in 2015 with life expectancy of

71.5 years. Unfortunately, this population growth has created poverty and affected ecologically fragile environments. Amman is the capital of Jordan and it is located in the central west part of the country. The official language of Jordan is Arabic, though many people speak English fluently (Jaradat & Gharaibeh, 2013). Amman; the capital, is located in the central west part of the country of Jordan and has gained its importance through history.



Figure 5.1: Political map of Jordan  
(Source: MapsOfWorld, 2015)

The nation of Jordan contains a diversity of landscapes and environments, a rich history containing many significant archaeological sites, and is bounded to the west by a major fault/plate boundary. Jordan can be divided into four ecological areas: the Jordan Valley, Highlands, Steppe and Badia (Arid) region (UNDP, 2009). Jordan has a combination of Mediterranean and arid desert climates, with Mediterranean climates prevailing in the north and west of the country, while the majority of the country is desert. Generally, the country has warm, dry summers and mild, wet winters, with



annual average temperatures ranging from 12 to 25 C (54 to 77 F) and summertime highs reaching the 40 C (105-115 F) in the desert regions. Rainfall averages vary from 50mm (1.97 inches) annually in the desert to as much as 800 mm (31.5 inches) in the northern hills, some of which falls as snow. Jordan maintains a dry climate throughout 90% of its area (UNDP, 2009).

Much of Jordan is desert (90% of its area); however, the north-western area is regarded as part of the Fertile Crescent. Generally, the country has warm, dry summers and mild, wet winters, with annual average temperatures ranging from 12° to 25° C and summertime highs reaching the 40° C in the desert regions. Rainfall averages vary from 50 mm annually in the desert to as much as 800 mm in the northern hills, some of which falls as snow (Jaradat & Gharaibeh, 2013).

Jordan's economy is among the smallest in the Middle East, with insufficient supplies of water, oil, and other natural resources, underlying the government's heavy reliance on foreign assistance. Other economic challenges for the government include chronic high rates of poverty, unemployment, inflation, and a large budget deficit. The Gross Domestic Product (GDP) in Jordan was worth 37.52 billion US dollars in 2015. The GDP value of Jordan represents 0.06 percent of the world economy.

### **5.2.2 National Hazard Scape**

Jordan is exposed to diverse natural hazards and disaster risks. The National Disaster Response Master Plan (NDRMP) of Jordan (2004) identifies the following main hazards as potential threats to Jordan: earthquakes, floods and flash floods, drought, locusts, and weather emergencies (snowstorms, frost), as well as human-made disasters such as fires, chemical dangers (industrial releases, hazardous materials transportation accidents, etc.), chemical, biological, and radioactive contamination, armed conflict, and mass population migration. Climatic hazards pose another set of threats to Jordanian economic and human development, particularly the droughts and flash flooding. A summary of major disasters over the past century is provided in Table 5.1. The table shows the disaster types, date, affected populations as (injured and displaced), and deaths (Jaradat & Gharaibeh, 2013).

In terms of the total number of affected people exposed to seismic, floods, landslides and climatic hazards, WHO (2011) indicated that more than 98.8% of Jordan population are potentially exposed to medium-high levels of seismic hazards. Similar, more than 3.5 million people will be inflicted by heat waves (10 years return period) as a consequence of global warming and climate change problems (see Figure 5.2).

Table 5.1: Major disasters in Jordan over the past 116 years

Year	Disaster type	Total deaths	Total affected	Total damage
1927	Earthquake	242	N/A	N/A
1963	Flood	25	N/A	N/A
1965	Flood	8	500	1000
1966	Flood	259	5792	1400
1981	Epidemic	4	715	N/A
1987	Flood	9	29	N/A
1989	Insect infestation	0	N/A	N/A
1991	Flood	8	18000	N/A
1991	Storm	2	N/A	N/A
1992	Extreme temperature	15	N/A	400000
1997	Flood	2	N/A	1000
1999	Drought	0	180000	N/A
2000	Drought	0	150000	N/A
2000	Extreme temperature	0	12	N/A
2000	Storm	9	200	N/A
2002	Storm	5	25	N/A
2004	Earthquake	0	19	N/A
2005	Terror attack	60	100	N/A
2006	Floods	6	25	N/A
<b>Total</b>	<b>19</b>	<b>654</b>	<b>355417</b>	<b>403400</b>

(Source: EM\_DAT, 2016)

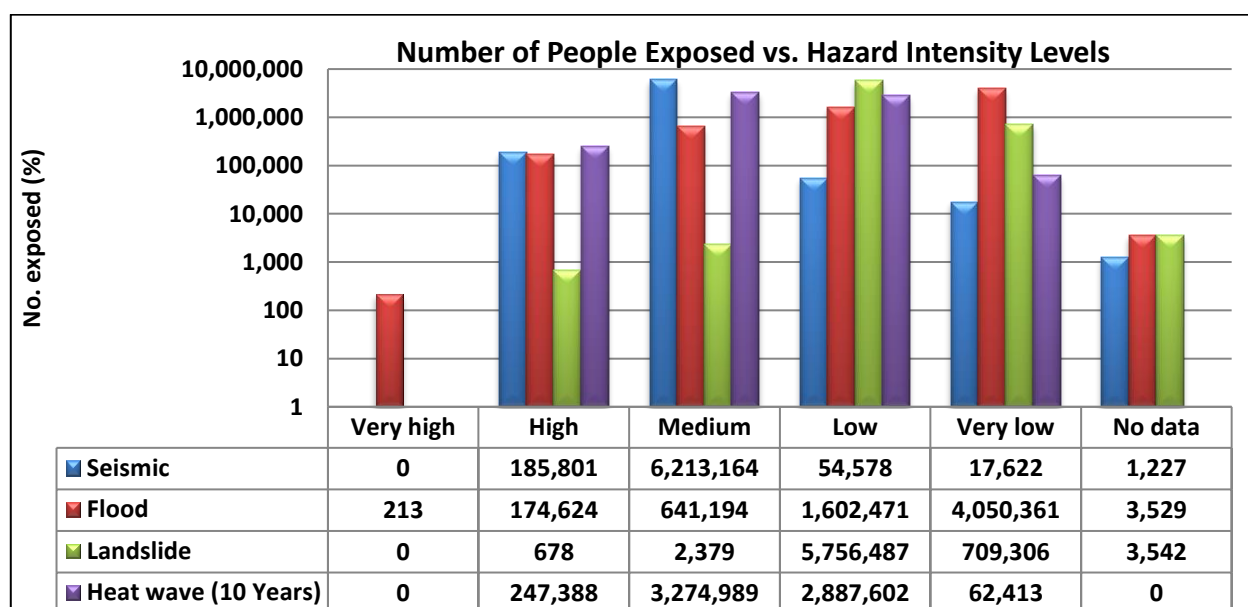


Figure 5.2: Exposed People to Natural Hazards in Jordan based on hazard intensity levels  
Source: WHO (2011)

### 5.3 Petra Region

Jordan is blessed with a rich collection of historical, religious and geographical attractions that become a main destination for tourism from regional, international and domestic visitors. The historical city of Petra is an important symbol of the rich culture of Jordan and of the involvement of Jordanian people in the broad and important currents of world history (Jaradat & Gharaibeh, 2013).

#### 5.3.1 Geography and demography

Currently Petra is governed by a special authoritative body called: Petra Development and Tourism Region Authority (PDTRA) (Figure 5.3). PDTRA was established in 2009, according to the Law of PDTRA (no. 15/2009) that was published on page (3830) of the Official Gazette no (4976) dated 17/8/2009, as a legal, financial and administrative independent authority that aims to develop the region's tourism, economy, society, culture and community. PDTR occupies the western regions of the Governorate of Ma'an (see Figure 5.4). Its elevation is 810-1545 metres above sea level. Its coordinates are: 30° 19' 43" N, 35° 26' 31" E. It is located within the southwest central part of Jordan. It is situated at 246 Kilometres south of Amman and 133 km North of the Gulf of Aqaba. Petra Region lies over an area of 766 square kilometres and populated by 32,092 inhabitants.

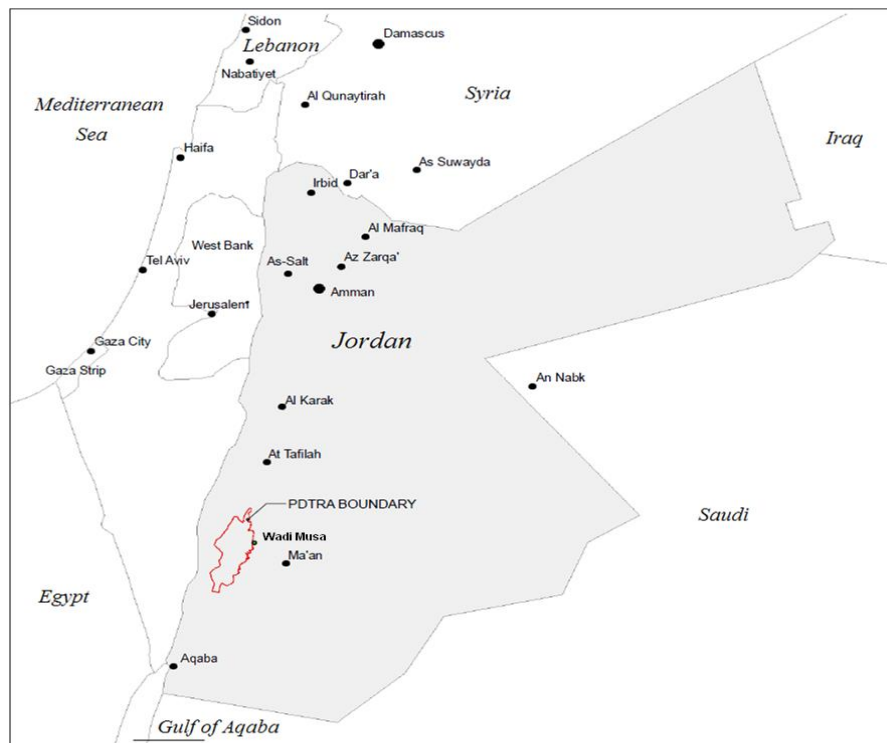


Figure 5.3: Location map of the Petra Development and Tourism Region (PDTR)

At present, the Region of Petra is composed of six major cities or towns; Wadi Mousa, Taybeh, Rajif, Dlagha, Umm Sayhoun, and Baidha (see Figure 5.5). The ancient City of Petra is currently designated as the Petra Archaeological Park (PAP) covering a total area of 264 dunums (264,000 square meters). This extensive tourist and archaeological site was registered in 1985 as a UNESCO World Heritage Site. This area is composed of an enchanting landscape with almost indescribable pink-hued rock mountains. In 2007, Petra was denounced as one of the New Wonders of the World. Tourists can see the basic sites in a day, but serious exploration would require several days (Jaradat & Gharaibeh, 2013).

In August 2007, The Jordanian government passed a law that converted Petra into an autonomous legal entity with separate financial resources. According to this new administrative arrangement, the management and maintenance of the Park is funded through multifarious sources that include: an allocation from the state budget, foreign aid, grants and donations, park entrance fees, and fees from services provided inside the Park. The PDTRA administrates the entire Petra Region (764 km<sup>2</sup>) including the Petra Archaeological Park (PAP), which covers 264 km<sup>2</sup>. The management of this section of land falls under the responsibility of the PAP, a subsidiary organization that reports to the PDTRA (Figure 5.4 PAP in the red) (Jaradat & Gharaibeh, 2013).

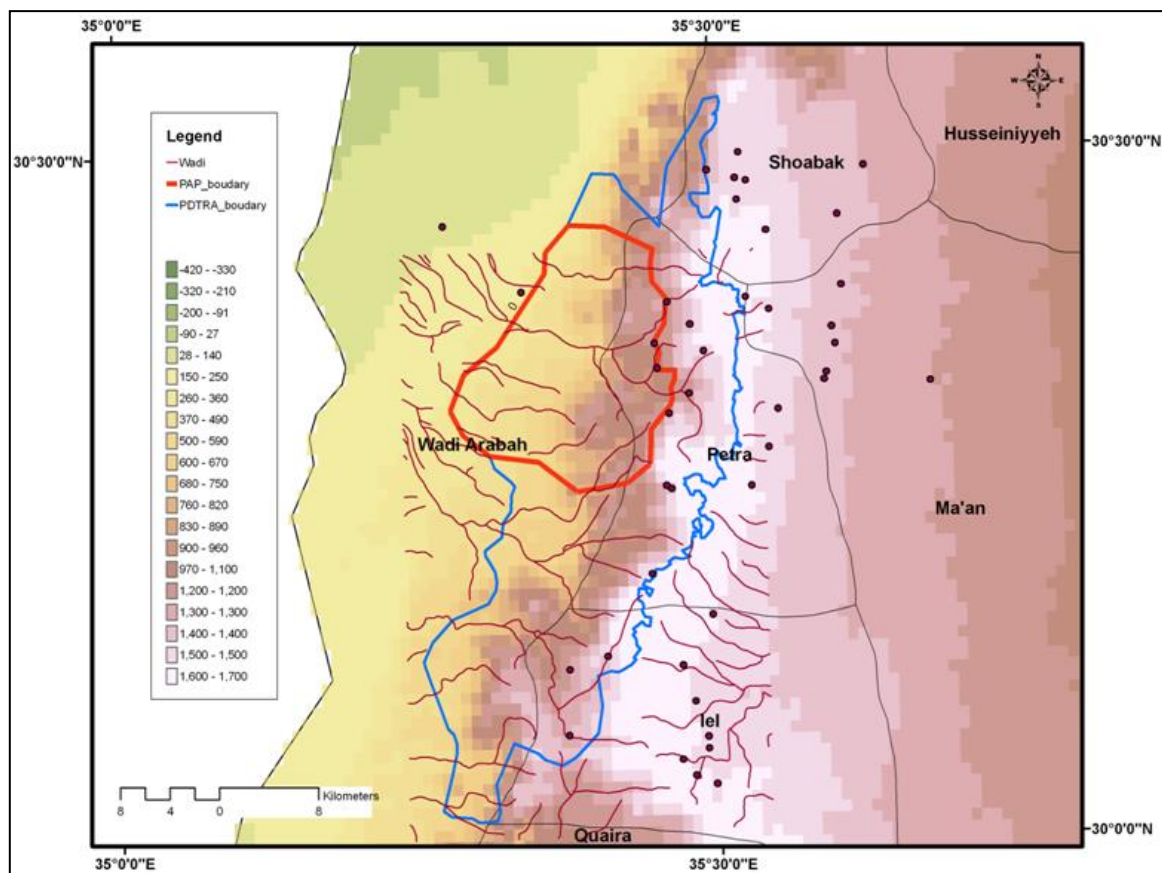


Figure 5.4: PDTRA, PAP, administrative boundaries and general topography of the Region

The PDTRA's new role is primarily focused on the development of the Petra Region to economically capitalize on its potential in tourism; PDTRA is also responsible for other areas such as local community development, heritage management and protection, and the environment (Jordan. Prime Ministry, 2009).

The weather is arid in the Petra Region with precipitation of 50-180mm per year (DOS, 2011 estimates). Average temperatures range between 5°-30° C, however there are some extreme times in the summer when temperatures may reach 45° (40° C at most, it never reached 45) and in the winter when they drop down to -10° C (-5° C at most). The variations in altitude and the rugged geological structures create temperature variations, wind tunnelling, and harsh sun effects depending on the precise location (Jaradat & Gharaibeh, 2013).

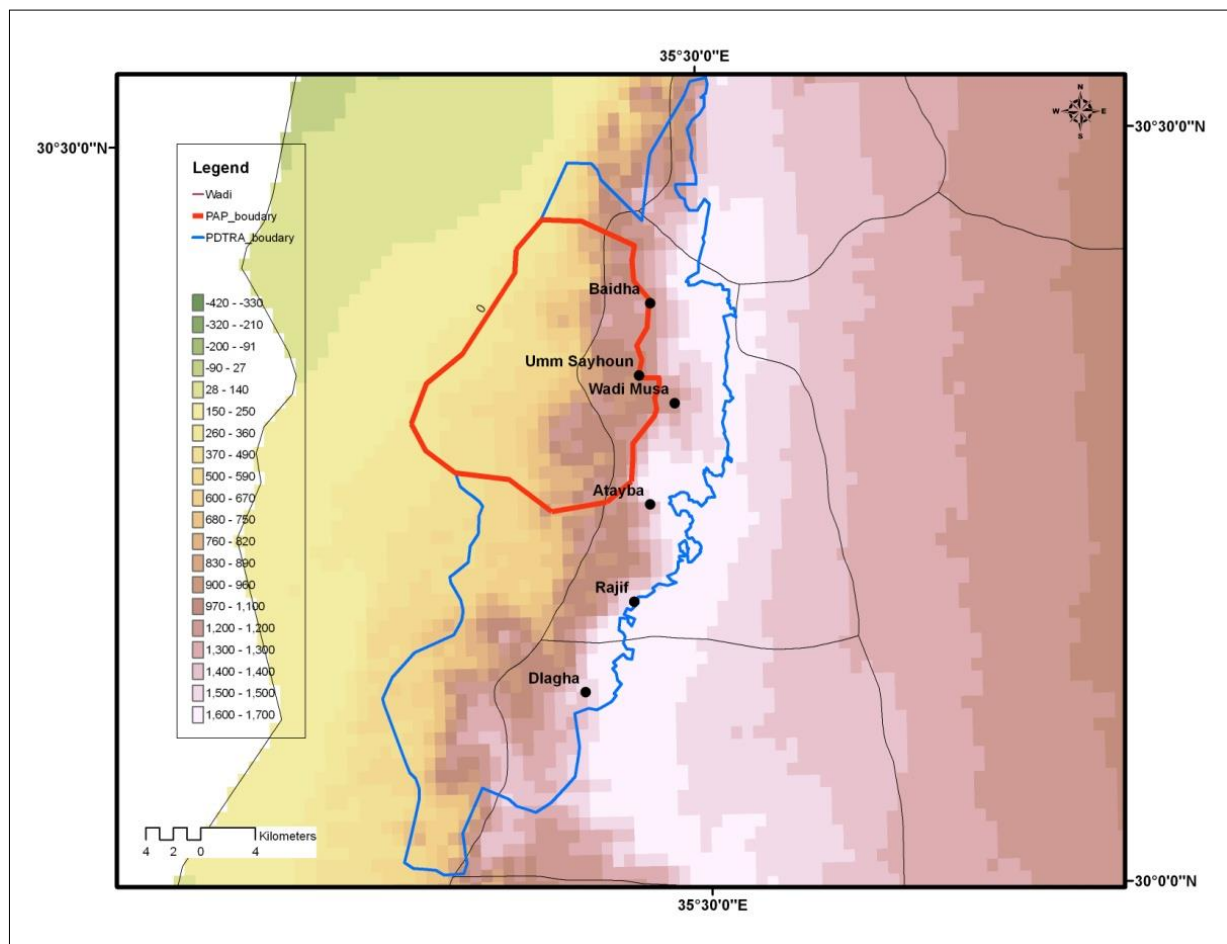


Figure 5.5: Major urban settlements of PDTR and PAP

Petra is considered an ephemeral wadi with intermittent flash flood of flows that can exceed the 298 m<sup>3</sup>/s thresholds. Its floods, however, do not flow every year. Nevertheless, at certain years the extent of flood can be huge (2.42 m<sup>3</sup>/sec was recorded as maximum mean daily discharge during January 1964). The surface drainage of the study area broadly divided into sub-catchments

according to drainage namely; the biggest tributary is wadi Alssadir sub-catchment, the second is wadi Jelwakh with wadi Khalil sub-catchment and the third is wadi Al Magir sub-catchment. Wadi Mousa is the confluence of the three sub- catchments (see Figure 5.6 the Conceptual scheme of the Petra catchment).

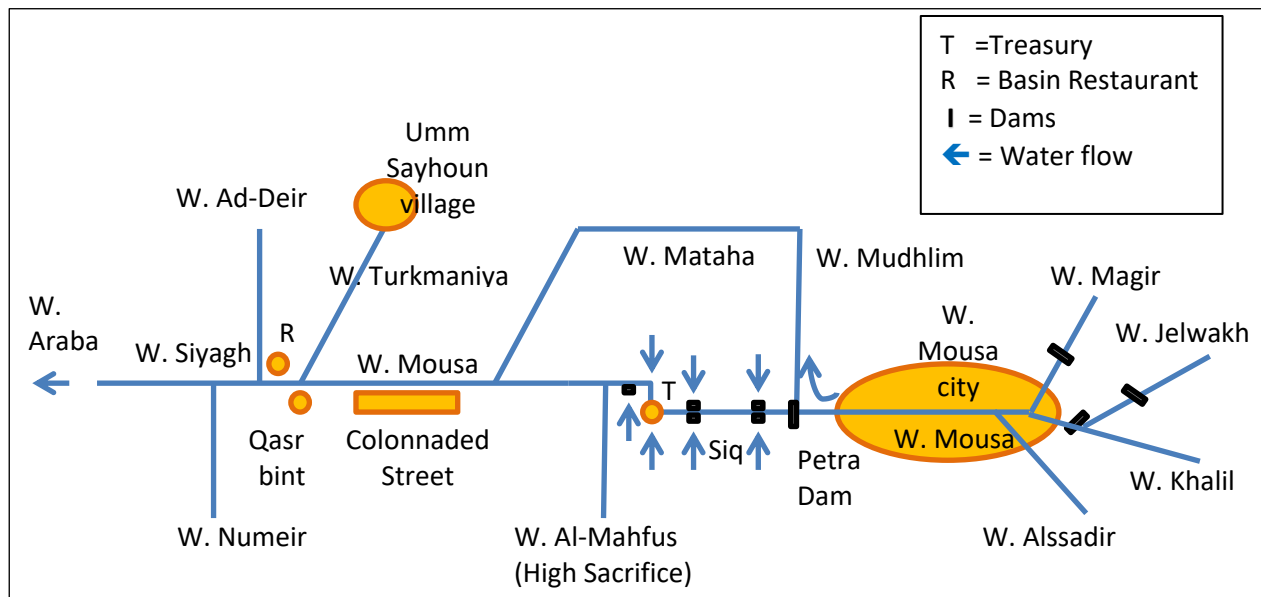


Figure 5.6: Conceptual scheme of the Petra catchment

### 5.3.2 The flash flood and its impacts

The effects of flooding in the Petra area were extensive and massive. According to historical records, the area has been hit by several rainstorms that have caused floods in the area, resulting in significant loss of life, infrastructure and public and private property. Table 5.2 shows the effects of floods in the Petra area over a period of about 50 years.

Table 5.2: Flash floods impacts at Petra Region (1963-2013)

Date	Casualties	Damages	Water Depth
Apr 1963	About 20 tourists	Wadi El-Yutim dam was destroyed	10 m
Nov 1968	None	N/A	5.3 m
Mar 1970	None	N/A	2.18 m
Jan 1974	None	N/A	4.3 m
1991	None	FF washed away two culverts	12 m
Apr 1994	None	Small old house damaged, cracks on main and sub-roads, bridges, damages on water and electricity networks	4.2 m
Nov 1996	One person	The Siq entrance area was flooded and tourists had to be rescued	5.4 m
Apr 2001	3 persons	Bridges, roads, private company machinery	7.6 m

Jan 2004	None	FF in Petra. Treasury flooded	3.4 m
Dec 2005	None	Airport Aqaba closed for 2 weeks	2.3 m
2009	None	Petra was flooded, some damages in the infrastructure	1.8 m
Jan 2010	None	Cracks in retaining walls and roads, some houses were flooded and have some damages	2.2 m
Dec 2010	None	About 3 retaining walls collapsed and cracks in roads, some houses were flooded and have massive damages	50 cm
Apr 2011	None	Petra was flooded, some damages in the infrastructure	1.95 m
Jan-Feb 2013 Feb 2013	None None	5 retaining walls collapsed or washed away, cracks in the main roads caused a collapsed of hotel under construction after one month, many houses were flooded and have massive damages. Estimated damages 5M-7M dollar	2.15 m 1-1.5 m
Nov 2013	None	More than 42 retaining walls collapsed cracked, or washed away, large fall in a road as a result of cracked retaining wall, housed were flooded and their furniture were damaged	1.5-2.5 m

Source: Documents from Petra Authority

The local governmental authorities have adopted many measures over many years to reduce and mitigate the impacts of flash flood. In 1963 after the massive damages and casualties that occurred due to flash flood, the local concern party at that time constructed a dam at the entrance (Siq) of the Archaeological Park (PAP), which contributed positively in reducing damages to the PAP. The local authorities have also adopted many measures in terms of disaster risk reduction such as the construction of dams, bridges, check dams, and water drainage systems, which helped reduce the death tolls as it presented in Table 5.2. On the other hand, damages in properties or infrastructure increased due to urban expansion which caused changing in the natural streams, climate change, and building in the valleys boundaries.

The economic losses were increased as shown in Table 5.2, the cost estimation of damages due to flash flood on Jan-Feb 2013 were at US\$ 5-7 million, not to mention the time consumed to reconstruct the damages and the effects on local communities' life and the effects on the tourist sector.

## **Part 2: Qualitative Data Analysis**

In this research, data collection methods used are a combination of different techniques such as interviews and documents.

### **5.4 Semi-Structured Interviews**

#### **5.4.1 Introduction**

In this section, the researcher attempts to analyse the captured data from semi-structured interviews. The interview aimed to capture the knowledge about: (i) the flash flood events and their impacts, (ii) the disaster risk management plans adopted by local government and communities to reduce these impacts, (iii) the role of the local government in mitigating flash flood risks and in increasing the region's resilience to flash flood disasters, (iv) the associated problems with the EWS's related to flooding.

The Researcher has prepared for the interview by: (i) selecting the appropriate candidates for interviews depending on the non-probability sampling technique adopted by researchers to collect data from specific participants who have knowledge and experience related to research objectives, (ii) implementing a pilot test in which the researcher aims to determine if there are flaws, limitation, or other weaknesses within the interview design, and (iii) allowing to make necessary revisions prior to the implementation of the study.

#### **5.4.2 Pilot Testing**

Preliminary analysis using the pilot test data can be undertaken to ensure that the data collected will enable the researcher to investigate questions (Saunders *et al.*, 2012).

During the first phase of data collection, three pilot interviews were implemented to examine whether: (i) the interview questions are structured to collect the desired data, (ii) the captured knowledge enriches research objectives with information. After implementing these pilot interviews, the researcher came up with the following results:

- Some of the interview questions were not completely understood by interviewees which led to inconsistent answers or no answer.
- The questions of interview were not suitable for some of the interviewees or exceeded their knowledge.
- Some of the interviewees answers comprised of a high-level data and explained the phenomena, whereas some other answers had exploratory data about the events of flash floods occurred in the study area and their impacts.



Due to the above results the researcher divided the participants into two groups based on their knowledge. Each group had 10 participants. Data would be gathered through semi-structured interviews with two groups of interviewees as following:

- Experts: a group of experts in flash flood field, has a high-level data, and could explain the phenomena of flash flooding. This group includes experts from: (a) top management participants from the local concerned authorities (b) academic sector (c) United Nation, non-governmental, communities-based agencies (d) independent experts in flood risk management (see Table 4.8 pp. 94).
- Users: a group of locals who can provide exploratory data about flash flood events occurred in the study area and how these flash floods affected the study area. This group includes participants from: (a) the tourist sector (b) the community leaders (c) the local authorities (see Table 4.8).

In the second phase, 20 interviews were conducted in total: 10 participants per interview, details of interviewees are shown in the Table 4.8. To simplify the discussion and analysis, the interviewees were coded as USER for user group and EXPT for expert group as shown in Table 5.3.

Interviews were limited to 20 interviewees because most of the data collected emerged in the first 7 interviews of each users' and experts' groups. The data collected became saturated after 10 interviews of each groups. This result matched with Guest *et al.* (2006) who stated in their research that data becomes saturated after first twenty interviews, and the 92% of data emerged from the first 12 interviews. The guidelines for semi-structured interviews and a sample of interviews for users group can be found in Appendix (B) and Appendix (D) respectively. The guidelines for semi-structured interviews and a sample of interviews for experts group can be found in Appendix (B) and Appendix (E).

Table 5.3: Semi-structured interview respondent codes

Interviewee	Code	Interviewee	Code
Interviewee1	EXPT_01	Interviewee11	USER_01
Interviewee2	EXPT_02	Interviewee12	USER_02
Interviewee3	EXPT_03	Interviewee13	USER_03
Interviewee4	EXPT_04	Interviewee14	USER_04
Interviewee5	EXPT_05	Interviewee15	USER_05
Interviewee6	EXPT_06	Interviewee16	USER_06
Interviewee7	EXPT_07	Interviewee17	USER_07
Interviewee8	EXPT_08	Interviewee18	USER_08
Interviewee9	EXPT_09	Interviewee19	USER_09

Interviewee10	EXPT_10	Interviewee20	USER_10
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The NVivo software was used to analyse the collected data from interviews. Interviews were categorised into four main themes. These themes were named as nodes in NVivo to simplify analysis (see sections 5.4.3 and 5.4.4).

### 5.4.3 Users Interviews

As mentioned earlier, interviewees represent: tourist sector, community leaders, and local authorities, aiming to collect exploratory data about the events of flash floods occurred in the study area and their impacts.

In the users group, the interview questions were constructed under four themes and 11 sub-themes, (see Table 5.4 for themes and sub-theme and). These themes and sub-themes were coded in NVivo (see Figure 5.7 coding structure for users)

Table 5.4: Users themes and sub-themes

Theme	Sub-theme
<b>Flash flood events</b>	(1) Flash flood events (2) Flash flood-prone areas
<b>Flash flood impacts</b>	(1) Effects of floods (2) Impacts of floods (3) Casualties
<b>Local Community preparedness</b>	(1) Training and awareness (2) Independent measures (3) Risk knowledge
<b>Local Authorities' Roles</b>	(1) Cooperation and coordination (2) Training (3) Commitment

Nodes		Look for:	Search In	Users
<ul style="list-style-type: none"> <li>Nodes <ul style="list-style-type: none"> <li>Interviews <ul style="list-style-type: none"> <li>Experts</li> <li>Interviewees</li> <li>Users</li> </ul> </li> <li>Relationships</li> <li>Node Matrices</li> </ul> </li> </ul>				
Sources				
Nodes				
Classifications				
Collections				
Queries				
Reports				
Models				
Folders				

Name	Sources	References
Flash floods events	0	0
Flash Floods Events	10	10
Flash Flood-Prone Areas	10	10
Flash floods impacts	0	0
Effects of floods	10	10
Impacts of Floods	10	10
Casualties	10	20
Local community preparedness	0	0
Training & Awareness	10	10
Independent measures	10	10
Risk knowledge	10	10
Local authorities' roles	0	0
Cooperation and Coordination	10	10
Training	10	10
Commitment	10	10

Figure 5.7: Coding structure for Users

#### 5.4.3.1 Flash flood events

The first theme in the users' interview was 'flash floods events' in which the researcher aimed to accomplish objective two of the study through investigating the knowledge that could be captured through the community members or other sector participants. This theme has two sub-themes; flood events, and flood-prone areas. The main question in this theme was "How many flood events have you encountered? And at what times? Were these events occurring when tourism was at its peak?"

##### 5.4.3.1.1 Flash Flood Events

When analysing this part, the researcher found that participants could be categorized into three categories:

- **First category:** who mentioned the number of flash flood events they witnessed or encountered with dates and differentiated if these events occurred when the tourism was at its peak or not. This category includes USER\_01, USER\_03, and USER\_04

According to USER\_01, flash flood events happened in 1996, 1999, 2001, 2010, 2011, & 2013. The 1996 flood was considered the most dangerous flood in the 1990s, whereas, the 2013 flood was considered the second most dangerous flood.

*"I encountered all floods events that occurred during the 1990s, the most important was in 1996, which was considered the most dangerous flood. In the current millennium, I encountered five flood events during the years 2001, 2010, 2011, 2012, and 2013, in which, the 2013 flood event was considered as the most dangerous one"* USER\_01 said.

These events are also repeated from USER\_03 as he said that:

*'During the last period, there were many floods that occurred in the area, such as floods in 1963, 1994, 1996, 2001, 2010, 2011, 2012, 2013, which were mostly in the winter months October and November. There have been some floods in the spring season, specifically in April and May during which tourism was at its peak'.*

And by USER\_04 who said that:

*"I encountered many floods in the region, especially the floods of 1994, 1996, 2001, 2010, 2011, 2012, and 2013. Most of these floods were in the winter months. They were not in the high tourist seasons, but a few of these floods occurred in the April (tourism season) which has had a clear impact on tourism for a day or two -when the closure of the archaeological site and preventing tourists to enter the site for their own safety- which negatively impacted Petra Region income from tourism, such as admission tickets, tourist facilities of hotels, restaurants, bazaars and so on"*

- **Second category:** Who mentioned that they witnessed some of the flash floods events, and differentiated between these events whether they occurred when the tourism was at its peak or not. Occurrence of flash flood events when tourism was at its peak added more impacts in the region, because when these events occur during the peak of the tourism, the local authorities close the archaeological site and this prevents tourists from visiting the site and tickets will not be sold. These participants are USER\_02, USER\_06, USER\_07, USER\_08, USER\_09, and USER\_10.

USER\_02 said:

*'I encountered one flood on March 2001 when the tourism was at its peak'.*

USER\_06 replied that:

*"I witnessed three events, in 2001, 2012, 2013. They were not at the peak of tourism"*

USER\_07 answered this question by:

*"Two to three flood events. They were in season of 2012/2013. These events were at the peak of tourism"*

USER\_08 encountered one flood in 2013:

*"I encountered one flood event, that was in 2013, but not when the tourism was at its peak"*

USER\_08 said.

*"I encountered five to six times. Times are 1996, 2001, 2004, 2010, 2012. Flood in 2001, was at the peak of tourism"*

USER\_10 finally said:

*"I encountered four times, 1996, 2001, 2012, 2013. All of these events were not when tourism was at its peak"*

After reviewing this category opinions, we found some of their answers conflict with other answers in terms of flash flood events occurrence when the tourism was at its peak.

- **Third category:** who witnessed flash flood events but he could not remember that exact date for these events, and they could not decide if these events occurred when tourism was at its peak or not, but just said that some of these events occurred when tourism was at its peak. This category has only one participant (USER\_05).

*"I witnessed all the floods that occurred after the fifties of the last century, in addition to floods in this century. I remember one of them in the 1960s caused a death of 28 French tourists, and another in the 1990s washed away number of cars. Some of these events occurred when the tourism was at its peak"* said USER\_05

After reviewing all interviews about flash floods events, it was found that they occurred as shown in (Table 5.5Table 5.5: Flash flood events for Petra Region (interviews result)) and some of these events happened when the tourism was at its peak which posed economic impacts at the local communities and at local authorities which benefit from tourism When the tourism is not at its peak, it leaves economic impacts. The occurrence of these events has left many damages in private and public properties besides the death of many people.

Table 5.5: Flash flood events for Petra Region (interviews result)

No.	Year	Tourism at peak	No.	Year	Tourism at peak
1	1963	No	6	2010	Yes
2	1994	No	7	2011	No
3	1996	Yes	8	2012	Yes
4	2001	Yes	9	2013	No
5	2004	Yes			

#### 5.4.3.1.2 Flash Flood-Prone Areas

The flood-prone areas were the concern of the second question answered by interviewees from different aspects. Generally, the natural behaviour of water (and flowing water) is that it moves

from higher ground to lower ground. This means if there is a higher ground adjacent to a lower ground, the lower ground is a lot more likely to experience floods. With the very steep topography of Petra Region it is likely that flowing water moves from higher places to lower places which experience floods.

Additionally, anywhere that rain falls, floods can develop. This is so because anytime there is more rain that brings more water through valleys (Wadi's) than can be drained or absorbed by the soil, there is a flood potential in low-lying areas and valleys boundaries.

In Petra Region, there are buildings springing up in many places where they have not been authorized. Some of these buildings are placed in waterways. Other places also have very bad and choked drainage systems. The danger is that, with the rain, water will find its own level if it cannot find its way. The result is flooding and these buildings could be flooded and under water.

The information collected from the interviewees is rich with description of these area. USER\_01 and USER\_04 mentioned that:

*"The flood-prone areas are the three-major valley areas in the region, Wadi Khalil, Wadi al-Saddir and Wadi Jelwakh and surrounding areas, due to the length of these wadis and the severity of its decline. These wadis are also gathering in one Wadi (Wadi Musa) at the entrance of the Petra archaeological Park (PAP) causing disastrous results in the archaeological site" USER\_01 said*

*"Flood prone areas are areas that are located near and surrounding the main valleys which are: The Valley of al-Saddir, the valley of Khalil, Valley of Jelwakh, Valley of Magir. All these valleys are gathering in Valley of Mousa, which leads to the entrance of the archaeological area that is the most flood-prone area" USER\_04 said*

USER\_02 supported:

*"Flood-prone places are close to the main valleys and sub-valleys, water culverts, mountainous slopes. The reason is due to the proximity of these places to valleys and a larger amount of collected rain water (catchments)"*

USER\_03 argues that majority of areas in the Petra Region are flood-prone areas:

*"The majority of areas in the Petra Region are flood prone areas, such as areas Jelwakh, Ain Moses, Zraizireh, Mukhaimar and Petra Archaeological Park (PAP) and the reason is due to its proximity to the main valleys"*

USER\_05, USER\_10 added other flood-prone area which near the entrance of Wadi Mousa City, main roads and downtown areas or tourism area, and gave

*"Mousa's spring area, main road, tourism area, downtown area. Because it is the confluence and gathering areas of the main valleys and there is no suitable water drainage system in these areas to accommodate the rain water properly" USER\_05 said*

*“The flood-prone areas are: Ain Mousa, tourism area, because of the mountainous nature of these areas, and also all valleys are gathered in the tourism area”* USER\_10 said

USER\_06, USER\_07, USER\_08, and USER\_09 talked in general about flood-prone areas and the reason after considering these areas as flood-prone area.

After reviewing the above replies, the flood-prone areas are as shown in Table 5.6

Table 5.6: Flood-prone areas – Users interviews

No.	Flood-prone area
1	Valleys (Wadi's); i.e. Ain Mousa, Jelwakh, Magir, Al-Saddir, Khalil, Valley of Mousa
2	Valleys (Wadi's) boundaries; i.e. Mousa's spring, Jelwakh, Zraizireh, Mukhaimar and Zoraba, areas
3	Water Streams; i.e. Zraizireh, Mukhaimar
4	Low areas; i.e. Tourism area, Zoraba, downtown, Petra archaeological Park
5	Building close to valleys and water streams; i.e. Hotels, houses and shops in tourist area

And the reason is due to the steep nature of the Petra region which leads to a larger amount of collected rain water (catchments).

#### **5.4.3.2 Flash Flood Impacts**

Floods had devastating consequences and had effects on the economy, the built environment, properties, infrastructure and the people. During floods (especially flash floods), roads, bridges, farms, houses and automobiles are destroyed. People become homeless. Additionally, the government deploys firemen, police and other emergency apparatuses to help the affected. All these come at a heavy cost to the people and the government. It usually takes years for affected communities to be re-built and business to come back to normalcy.

The environment also suffers when floods happen. Chemicals and other hazardous substances end up in the water and eventually contaminate the water bodies that floods end up in. Additionally, flooding kills animals, and other insects are introduced to affected areas, distorting the natural balance of the ecosystem

Many people and animals may die or get injured in flash floods. Water supply and electricity are disrupted and people struggle and suffer as a result. In addition to this, flooding brings a lot of

diseases and infections. Sometimes insects and snakes make their ways to the area and cause a lot of havoc.

There is also something good about floods, especially those that occur in floodplains and farm fields. Floodwaters carry lots of nutrients that are deposited in the plains. Farmers love such soils, as they are perfect for cultivating some kinds of crops.

The second theme in the users' interviews was the flash flood impacts in the study area, in which the researcher aims to achieve second objective of the research study. This theme was divided into three sub-themes: effects of floods, impacts of floods and casualties due to floods, aiming to give more details about flash floods direct and indirect impacts in the area.

Every flash flood occurred in the study area has left damages in private or public properties, threatened people lives and may have caused some casualties, effected the economic, social, and/or tourist sectors. Some damages were huge and some others were minimal depending the severity and intensity of the flood. In the next three sections, interviewees replies will be analysed.

#### **5.4.3.2.1 Effects of Floods**

As mentioned in 5.4.3.2, flash floods affected the people, properties and all sectors in the study area. Effects occurred in the study area due to flash flood varying from event to another depending on its severity or intensity. In this section, the interviewees' answers in this regard might shed light on these effects in more details. The users group interviewees have talked about these damages in their interview in different ways.

USER\_01 concentrated on the direct and indirect flooding effects on the economic and tourist activities besides the effects on local community life, he said:

*"There are direct and indirect flooding effects on the economic and tourist activities represented in:*

- Closing the archaeological site for a day or more, thus depriving the PDTRA and the local community from the proceeds of entering the archaeological site*
- Some houses and shops had been flooded and caused damages to the furniture or goods.*
- Some public and private properties such as cars and livestock exposed to risk of drift"*

USER\_03, USER\_04, and USER\_07 supported USER\_01 and added that flash floods affect tourism activities because the local authorities in Petra close the archaeological site and does not allow tourists to visit it to prevent them from any possible risk, and that of course will affect the economic



return of the region. USER\_03 explains that effects occur if flash floods take place when the tourism is at its peak:

*“Flash floods affect tourism activities, particularly when flooding takes place in the high tourism season, because of the closure of the Petra archaeological park (PAP) to prevent any possible risk may the tourist and visitor be exposed to, which reduces the region's income from tourism, such as admission tickets, income of tourist facilities of hotels, restaurants, bazaars and so on. Moreover, this matter negatively affects economic activities, where declining sales and thus low financial return on the economic sector in this area” USER\_03 said*

USER\_04 supported by adding that:

*“Flash flood events were affecting the tourism activities in the winter because of the closure of Petra archaeological park (PAP) against tourists and thus cancel their entry which leads to the cancellation of entry tickets and hotels and restaurants booking as well as the low sales of antique shops and bazaars in the region. This is a negative impact on the economic activities due to low sales and hence lowering financial return on the stakeholders in this area. Add to this, the region's need to rehabilitate areas affected due to the floods by the authorities, which lead to the depletion of its financial resources on other projects account”.*

USER\_07 and USER\_08 argue that the effect on the tourism and economy are not that major effects due to the availability of infrastructure in the Petra Region:

*“There is an effect, but not a major effect in the tourism and economic activities in the region due to the availability of infrastructure by the Petra Authority in the region, which was the cause of the reduction of the effects of the floods on the region risks” Said USER\_07*

*“From my point view, there was no clear impact on tourism and economic activities in the region because of floods” Said USER\_08*

The other interviewees considered the effects on the tourism activity due to flash floods as insignificant. USER\_02 and USER\_05 argue that these events confine to specific locations and at the time of the flooding, so the risk could be overcome by calling for full mobilisation of all official and public parties:

*“From my perspective, there was no significant impact on tourism activities as the flood confined to specific locations, so the risk could be overcome in a few hours” Said USER\_02*

*“There is no lasting impact on tourism and the economic activities, except at the time of the flooding which calls for full mobilization of all official and public parties” Said USER\_05*

The last two interviewees – USER\_09 and USER\_10- claimed that flash flood events did not affect tourism activities. However, they claimed that flash flood events affected economic activities such as: a reduction in investment and construction due to water damage to the land, loss of citizens’

properties to water damage to their furniture and vehicles. Such damages result in a high cost to the government since they have to provide better protection measures to local citizens.

USER\_06 and USER\_10 argues that there is an economic effect on citizens who require necessary protection:

*“There is no significant impact on the tourism activity of the floods, but there is an economic impact on the citizens and the governmental institutions dealing with infrastructure, the fact that the citizen requires the necessary protections as he starts carrying out construction” (incomplete idea) USER\_06 said.*

*“Floods, from my perspective, did not affect the tourism activities, whereas, the economic activities were affected by these events. Some houses and shops had been flooded and caused damages to the furniture or goods, some public and private properties such as cars and livestock were exposed to risk of drift” USER\_10 said.*

After reviewing this part of interviews, it was concluded that flash flood events have left many effects on the tourism, economic, and social sectors, besides the effects on the infrastructure in study area. Some other details about flash flood effects will be reviewed through the documents section.

#### **5.4.3.2.2 Impacts of Floods**

The second sub-theme in this category is the impacts of floods. As mentioned earlier in the literature review section 2.3.4.1, Petra region has been exposed to flash floods that posed major and serious threats to Petra Region and the tourist and local activities in Petra as well as to the monuments themselves. In this section, it is intended to review what participants in users group have said about these impacts.

Some of the interviewees such as USER\_01, USER\_03, USER\_04, USER\_05, USER\_06, USER\_09, and USER\_10 have pointed to the significant losses in infrastructure and local community properties due to flash floods in particular. Moreover, some of the participants gave some examples, while others mentioned these losses or impacts in general.

The losses that occurred due to flash floods were categorised to public and private losses as mentioned by USER\_01:

*“Floods led to significant losses in infrastructure in the region, such as:*

*1-collapses in some roads and retaining walls*

*2- erosion and damage to large parts of the drainage systems and networks of drinking water and electricity networks.*

*As for private property losses were:*

*1-collapses or cracks in the walls of houses*

*2-homes flooded, which led to damages in furniture and electrical appliances”*

This was supported by USER\_03 who added:

*“There are a lot of negative results caused by the floods that occurred in the area, such as cracks in the roads and retaining walls and the collapse of some parts of them, rainwater culverts and their channels, in addition to the erosion of some sidewalks.*

*Regarding the public properties, there were cracks in some buildings, sewage systems, water and electricity networks. Private properties were not immune to these effects. Collapses or cracks in the walls of houses, flooding houses, damages inside the houses such as furniture, electrical appliances”*

And USER\_04:

*“Floods led to significant losses in infrastructure in the area: collapses in roads and retaining walls, rainwater channels and sidewalks roads, and led to losses of public properties such as cracks occurred in some public buildings and the collapse of some of the sewage and drinking water lines and electricity network.*

*As for private property, some landslides occurred in the walls of houses and raiding water to households, which resulted in losses within citizens’ homes, such as furniture, electrical appliances, as well as cracks in some houses which need to rehabilitate” USER\_04 said*

It is very clear that local community properties are more exposed to flash flood impacts due to the lack of preparedness measures the owners adopt to protect their properties. Interviewees USER\_07 and USER\_08 said that there is a limited or slight impact on infrastructure but severe impact on the local community properties.

*“floods led to a limited impact on infrastructure, but caused a severe impact on the property. Also, their owners did not provide the necessary means of preparedness or preventive measures to reduce the impact of flood risks, especially properties that resides in the valleys, which make them vulnerable to flooding” Said USER\_07*

*“Floods led to slight impact on infrastructure but severe impacts on public and private properties” Said USER\_08*

The other impacts were of other type such as washing away some roads and irrigation canals used by farmers which added an environmental impact as mentioned by USER\_02:

*“There was obvious impact on the infrastructure, such as washing away agricultural roads and irrigation canals used to irrigate crops and the demolition of some retaining walls”*

As previously shown, there were severe impacts in infrastructure, besides the impacts at the local community properties. These impacts could be summarised as in

Table 5.7

Table 5.7: Impacts of floods at public and private sectors

Impacts at public	Impacts at private
Collapses in some roads and retaining walls	Collapses or cracks in the walls of houses
Erosion and damage to large parts of the drainage systems, rainwater culverts and networks of drinking	Damages in furniture and electrical appliances
Erosion of some sidewalks and agricultural roads	Damages of vehicles
Cracks sewage systems, water and electricity networks	

#### 5.4.3.2.3 Casualties

The third and final sub-theme in the flash flood impact category is the casualties which may occur due to flash floods or any other disaster.

Many people and animals had died in flash floods. Many more were injured and others made homeless. Water supply and electricity were disrupted and people struggled and suffered as a result. In addition to this, flooding brought a lot of diseases and infections. Sometimes insects and snakes made their ways to the area and cause a lot of havoc. According to many researchers and eye witnesses, casualties in the study area were high due to flash flood occurred in 1963; 20-30 tourists died which caused the local authorities to adopt some prevention measures to protect and reduce casualties. Therefore, flash floods occurred after 1963 up to present day did not left any casualties in Archaeological sites.

In the other parts of the Petra Region and due to flash floods, that took place in 1996 and 2001, one and three persons died respectively. This also led the local authority Petra Development and Tourism Region Authority (PDTRA) to adopt more prevention measures to reduce flash flood impacts. These measures were successful in terms of reducing casualties whereas material losses did not reduce, but rather increased and became financial charges on the government and the local citizen.

As the interviews implemented for Users group and asked the interviewees about the casualties through questions 6 and 7, most of the answers were telling that there were casualties and the highest was in 1963 with some differences in numbers of deaths in that year due to lack of documentation and database at the time. Almost all of the interviewees mentioned that they witnessed the flood of 1996 which left one death and flood 2001 which left three deaths, whereas they only heard about the flood of 1963 which left 20-30 deaths.

USER\_01 mentioned that:

*"One of the events that I have witnessed during the flood in 1996, a young man drowned in a flood and died. I heard from my father that during the sixties of the last century occurred a great torrent that claimed the lives of about 28 French tourists and a guide from the local community"*

And he added that:

*"The highest number of casualties were due to flooding in 1963 that led to the deaths of 28 French tourists as well as a local guide in the Siq area. The reason after that was due to the absence of a dam in the beginning of Siq to reduce the impact of the flood on the archaeological area or conversion of the riverbed from the entrance of the archaeological area"*

USER\_02 depends on what he heard and agreed with USER\_01 for the highest number of casualties:

*"According to the chronology of events, and as we heard from our parents, the flooding has occurred in 1963 and claimed the lives of about 29 French tourists in addition to the guide of the local community. And, in 1996 a flood occurred that killed a boy at the age of 15 years"*

*"The highest number of casualties were in the flood that occurred in 1963 and the reason is due the absence of a dam to prevent water entry into the Siq in the ancient city of Petra"*

USER\_03, USER\_04, USER\_06, USER\_07, USER\_08, USER\_09 and USER\_10 mentioned the casualties occurred in 1996 and 2001, they mentioned that there were losses of life. In 1963, 20-28 French tourists drowned as well as a local guide. In the flood of 1996, another person from the local community died. In 2001 another flood occurred which led to the drowning of 3 people from the local community

The largest human losses that occurred in 1963 were due to the lack of dam or barrier at the Siq of Petra, which led to a rush of water inside Siq of Petra and the sinking of the French tourists and the local guide at the time.

*"Yes, there have been some casualties in 1996 and 2001. In 1996 there was one person, and three persons in 2001"*

*"The biggest casualties were caused by the flooding in 1963 which led to the deaths of 28 French tourists as well as a local guide in the Siq area. The main cause of the flood was due to the absence of a dam in the beginning of Siq to reduce the impact of the flood on the archaeological area or conversion of the riverbed from the entrance of the archaeological area"* said USER\_05

*"Yes, there have there been casualties in the past due to the floods. There were 28 tourists in 1963, one person in 1996, and 3 persons in 2001."*

*"In 1963, I think the casualties were the highest; 28 French tourists and local guide. Because of the high level of water which flooded the entrance of Petra"* said USER\_09

It is concluded that there were casualties due to flash floods in Petra region. The most well-known are summarised in Table 5.8

Table 5.8: Flash floods casualties

Year of Event	No. Of Casualties
1963	20-29
1996	1
2001	3

It could also be concluded that the reason behind the casualties in 1963 was the absence of dam or barrier at the entrance of Petra's Siq.

#### **5.4.3.3 Local Community Preparedness**

Disaster preparedness is everyone's business. There are many hazards which threaten local communities in Petra Region such as flash floods. When these flash floods happen in the Petra community, they may affect their lives and resources causing disastrous situations.

To know how to respond to flash flood's possible threats, the community needs to be organised and prepared with the correct information and tools to be effective. Therefore, the community should be prepared and educated on what to do in the event of flash flood to reduce losses and damages that may result by disaster. The things should know are like: how to evacuate their homes when necessary, where the nearest emergency shelters are located, what essential items to bring, flash flood information, weather forecasting. To examine the adopted measures in terms of local community preparedness, this theme was designed within the interviews. Interviewees answers were collected, analysed and summarised in the next section.

##### **5.4.3.3.1 Independent Measures**

As mention in section 5.4.3.3, the local community can respond to flash flood threats if local community is prepared and aware of the actions to follow in case of flooding, besides the independent measures that have been adopted by the community to reduce flash flood threats.

According to USER\_01, Local authorities used to send or broadcast messages and instructions to citizens through various means to raise their knowledge of the procedure that they must follow in the events of flooding.

*"There are some messages and instructions broadcasted to citizens through various means to raise awareness that included instructions that must be followed in the event of flooding."*

USER\_01 said

The workshops and involvement of local community in the flood risk reduction added a value in terms of preparedness of community as mentioned by USER\_02:

*“Petra Authority has conducted a number of workshops in this regard as well as the partial involvement of the local community in the flood risk reduction”*

USER\_03 argues that knowledge about the flooding and the actions to be taken in case of flooding gained through citizens’ experiences and frequent flooding in the area as well as awareness lectures. Moreover, the local citizen is usually keen to adopt measures to protect himself, his family, and his property.

*“There is a medium knowledge through citizens’ experiences and frequent flooding in the area as well as some awareness lectures, which must be intensified to raise awareness and thus reduce the potential risks. I mentioned here that the citizen is usually keen to take measures to protect himself and his family and protect his property through the establishment of the small channels around his house to keep water away from home, own some of the hand tools to convert torrents pathways from his home for protection, as well as staying away from the floodplain and valleys, not to mention taking the necessary precautions of having a source of illumination to use during power outages as well as water and food reserves to avoid going out in the flood times.”* USER\_03 said

The knowledge could be basic and needs to be enhanced with good measures to minimise exposure to risk as mentioned by USER\_04 and USER\_06

*“There is a simple knowledge through awareness lectures but not sufficient, but the knowledge of the citizen lies in the measures, which are carried out to protect himself and his family and protect his property through the work of the small canals around his house to keep the water from home, set up walls that protect his home from landslides, stay away from the floodplain and valleys, having a source of illumination for use during power outages as well as water and food reserve.”* USER\_04 said

*“There is a basic knowledge among citizen of measures that he must follow in case of floods such as stay away from the valley streams and areas subject to flooding. Local citizen adopted some measures that contribute to minimise the exposure of himself and his property to the flooding, such as retaining walls around his property, water drainage systems, establishment of terraces that prevent entry of water to his house, move away from the valleys and areas prone to flooding.”* USER\_06 said

Local citizens are familiar with the nature of the study area and know how to behave in such circumstances, as mentioned by USER\_07

*“The local citizen is familiar with the nature of the area and knows how to behave in these circumstances, moreover, the citizen takes some actions to protect himself and his property from flood risks, such as walls and water channels and discharge systems.”* USER\_07 said

USER\_10 argues that there should be competent authorities to deal with floods and there should also be a link with the official bodies.

Finally, the procedure that might be followed in case of floods is generally known by local citizens but could be enhanced by workshops and awareness campaigns. Most of citizens have undertaken independent measures to protect themselves and their properties from floods.

#### **5.4.3.3.2 Risk Knowledge**

Risk knowledge is an important part of community preparedness. In which the community members are aware of the risk they are exposed to in the area such flash floods. Creating an understanding of the underlying disaster is crucial in reducing vulnerability to disasters. Therefore, workshops are a popular vehicle to communicate messages about flooding and risk reduction which leads to community empowerment to participate in reducing disaster risk. Moreover, providing information about the approaching hazard will help the local citizen to take actions to protect himself and his properties, to evacuate when it is required, and adopt measures to minimise the disaster’s effects.

According to USER\_01, USER\_03, USER\_04, and USER\_10 the local community seeks information from media and weather forecast that mainly depends on the Jordan Meteorological Department (JMD).

*“Through the media and weather forecasts. The weather forecasts are mainly depending on the Jordanian Meteorological department which is specialised in the forecasting and owns modern instruments to forecast besides the specialized technical personnel. I am satisfied to some extent with this information”* USER\_01 said

*“I seek information from the media, local authorities, friends and citizens who are close to flooding areas. Yes, I am happy with such information”* USER\_03 said

*“Through the media and weather forecasts. The weather forecasts are mainly depending on the Jordanian Meteorological department. I am quite happy with this information”* USER\_10 said

Some of the local community members seek information via Petra Authority or friends who are close to flood areas as mentioned by USER\_05:

*“Information we obtain is sourced from the media, local authorities, such as the authority of the Petra region, civil defence, friends and citizens who are close to flooding areas.”*



USER\_06, USER\_07, and USER\_09 mentioned that local community seeks information through JMD, but they claim the information is not accurate enough, inadequate, and limited. They are also not satisfied with this information.

*“The information obtained from the Meteorological Department, which often cannot afford to give the correct information. I am not satisfied with this department”* USER\_06 said

*“Through Meteorological Department, however, this information is not accurate or reliable because of many mistakes that occurred in the forecasts that were issued by this department. Therefore, lot of people depend on the forecast of internet sites”* USER\_07 said

For the adjustment that may be needed in terms of the availability of information about floods, most of the interviewees mentioned that the data should be available and easy to access for inhabitants in the area in general and for whom is at risk. Data could also be provided through websites of the local authorities, social media, and billboards at most accessed place in the region, and at information windows in visitor centre for the Petra tourists.

*“For the adjustments needed in terms of information about floods, the data should be known and easy to access for all inhabitants in the area especially in rainy seasons, and that may be putting the data in the websites, local media, social media, and could be shown in billboards located in the city centre and the visitor centre.”* USER\_01 said

*“Regarding the adjustment needed in terms of information about floods, information is very important and should be available and accessible to the local community, such as putting this information at social media and may be the radio and the T.V. For Petra tourists’ it could be provided via billboard or information window at visitor centre.”* USER\_05 said

It is concluded that most of local community seeks information from media and weather forecast that mainly depends on the Jordan Meteorological Department (JMD), but they claim the information is not accurate enough, inadequate, and limited. They are also not satisfied with this information. Whereas some of the local community members seek information via Petra Authority or friends who are close to flood areas.

For the adjustment that may be needed in terms of the availability of information about floods, the data should be available and easy to access for inhabitants in the area in general and for whom is at risk. Data could also be provided through websites of the local authorities, social media, and billboards at most accessed place in the region, and at information windows in visitor centre for the Petra tourists.

#### 5.4.3.3.3 Training and Awareness

The last issue in the local community preparedness is the training and awareness which could be the most important measures in the community preparedness. The community-based disaster risk management

Raising awareness about community-based disaster risk reduction; disaster prevention, mitigation and preparedness; among DRR stakeholders and vulnerable groups such as citizens, children and women, private economic sector, tourist sector, could be achieved by using various means such as awareness classes, door-to-door campaigns, and training. In the awareness and training programmes, many issues must be clarified for those of vulnerable groups such as: the evacuation plan, shelters, alternative roads, medical care centres, ...etc.

According to most of USER group interviewees, there were a few and limited awareness programmes but no training programmes directed to local community held by Petra Authority or civil defence, such as lectures in schools or workshops on flooding risk.

*“There are a few awareness programs, but limited in either lectures per day in schools or workshops to raise awareness of the flooding risk.”* USER\_01 said

*“I heard about the workshops on warning systems and disaster risk in general, but were not enough and there are no training programs for Local Community.”* USER\_03

*“Petra Authority held a workshop on warning systems but were not enough. There are no training programs for the community, but only for students in schools by the Authority and civil defence for one time.”* USER\_04 said

USER\_05 argues that these awareness programmes are directed to those who are interested in this matter and have the follow-up to such programmes. Whereas USER\_10 mentioned that these programmes should be comprehensive training and awareness programmes directed to local community, especially the vulnerable people:

*“There are a few awareness programs, but limited in either lectures per day in schools or workshops to raise awareness of the flooding risk. There should be a comprehensive training and awareness programmes directing local community especially the vulnerable people, in addition to the emergency teams whom in charge to deal with flash flood.”* USER\_10 Said

It is concluded that local concerned parties in disaster risk reduction should have a comprehensive training and awareness programmes to local communities in general and to those at risk and emergency teams whom in charge with flash flood in particular, and these programmes have to be implemented periodically. In the next section, the local authorities' roles in terms of disaster risk reduction will be discussed and training issue will be presented as a role of local authorities.

#### 5.4.3.4 Local Authorities' Roles

The local authorities' roles may be summarised as following:

- Regulatory arrangements that protect life, property and the environment through:
  - Ensuring that all local disaster planning and preparedness measures are taken.
  - Routinely conducting disaster risk assessments on their communities.
  - Ensuring there are adequate local disaster response resources, including volunteer resources.
  - Reducing hazards through land use planning
- Ensuring the provision of appropriate public disaster awareness, education and training, and local warning systems
- Primary responsibility for providing adequately prepared and capable emergency services directly to the community and representing community interests in disaster management to other levels of government

In this section, the interviewees were asked about three main things: (i) cooperation and coordination between government institutions and local community organisations to reduce flood risk, (ii) the responsibility of training and awareness of the local community, (iii) and the commitment of governmental institutions.

##### 5.4.3.4.1 Cooperation and coordination

USER\_01, USER\_02, USER\_03, USER\_07 and USER\_09 stated that there is a good coordination between governmental institutions during emergency time such as floods:

*"There is a good coordination between government institutions during emergency time such as floods" UER\_01 said*

He added that:

*"Some institutions are working to raise public awareness of the possibility of flooding and guide citizens to take precautionary measures before it occurs."*

USER\_02 mentioned that there is a coordination between governmental authorities and United nations agencies such as United Nations Development Programme (UNDP):

*"There is coordination between the so-called non-governmental organizations such as UNDP and governmental authorities to reduce the risk of flooding projects were cooperating through the provision of technical support, capacity building and the establishment of monitoring stations for the flood"*

USER\_04 supported:

*"There is a coordination to some extent between government institutions from one side and the local community and its institutions from other side in order to reduce the flood risk. The local*

*community cooperates in opening roads by its machineries, removing bailout, and contributes to the rescue of citizens in the areas of danger and save their properties.”*

USER\_07 also mentioned this coordination and cooperation:

*“There is cooperation and coordination between government institutions and the local community and its institutions to reduce disaster risk, which appears largely through Emergency Operation Centre (EOC) in case of emergencies and coordination of the work of Machineries and human resources.”*

Some of the interviewees stated that there is no cooperation or coordination between these parties such as USER\_08 and USER\_10:

*“There is no cooperation and coordination between government institutions and local community, community-based organisations to reduce flood risk.”* USER\_08 and USER\_10 said

It could be concluded from the above opinions that there is coordination and cooperation between governmental institutions in terms of flash flood risk reduction, but limited with local community agencies.

#### **5.4.3.4.2 Training**

Most of the interviewees; such as USER\_01, USER\_03, USER\_04, USER\_07, and USER\_09 believe that the Civil Defence in collaboration with Petra Authority are the parties that must provide training, on how to deal with the flash floods, to the local community and other sectors of the tourism and schools, and universities. USER\_01 stated that:

*“The concerned authorities for flood disaster reduction training and awareness program should be conducted by all concerned parties, particularly the Civil Defence, Petra Governorate, and PDTRA.”*

USER\_03 and USER\_04 supported”

*“Civil Defence in collaboration with Petra Region Authority, Petra Governorate in addition to public security.”* USER\_03 said

*“Civil Defence in collaboration with Petra Region Authority and Petra Governorate in addition to public security should train and make more awareness”* USER\_04 said

USER\_02, USER\_06, and USER\_10 believe that this role relies on civil defence only, who should train people:

*“The party who should train citizens and create more awareness are civil defence teams and specialists in this field of experts and technicians.”*

USER\_06 and USER\_10 supported:

*"The concerned authority is the Civil Defence who should train and make more awareness"*  
USER\_06 said

*"Civil Defence should train citizens and raise their awareness"* USER\_10 said

Whereas some other interviewees argue that training is Petra Authority's responsibility. USER\_05 said:

*"Concerned people in Petra Authority should take over all the training and awareness programmes which should also be directed to local communities besides the training for the concerned parties in flood management."*

USER\_08 supported and talked about trainer qualifications:

*"The Petra Authority who should take over the training process. Moreover, the trainer should have information and adequate expertise in the training."*

It is concluded that training and awareness process should be implemented by the parties that deal with flash flood events, and they should hire qualified trainer with adequate information and experience to deliver this information to local community members and any other sectors whom require this training.

#### **5.4.3.4.3 Commitment**

Many interviewees admit authorities in the region do not lack commitment, and the commitment is acceptable, but the lack of resources may affect or limit this commitment. USER\_01 said:

*"There is acceptable commitment but sometimes the lack of equipment, lack of sufficient number and appropriate type of machinery may limit the effective intervention to reduce the impact of floods in the region, in addition to that the absence of major projects such as water harvesting projects to take advantage of rain water and reduce its impact."*

USER\_02 and USER\_05 supported:

*"Sometimes lack of commitment is due to a lack of resources."* USER\_02 said

*"No, but there is a big commitment from the local authorities and especially the Petra Authority in dealing with the floods and infrastructure works to reduce flood risk, such as dams and rainwater discharge systems and protect the streets and houses of flood risk by retaining walls."*  
USER\_05 said

Finally, it is concluded that the commitment of local authorities is acceptable to some extent depending in the available resources in these authorities such equipment, sufficient number and appropriate type of machinery, qualified teams to deal with flash flood events. Therefore, the local concerned authorities need to deal with flash flood events effectively and show more commitment.

The overall findings from users' interviews data analysis about the role of local authorities in terms of disaster risk reduction indicate that:

- There is some coordination and cooperation between the local authorities concerned with reducing disaster risk, while it is almost non-existent with the local community institutions.
- Training and public awareness; which are the responsibility of the civil defence and the authority of Petra, are considered inadequate and implemented in a limited way in the study area.
- Local authorities show some commitment to the local community and other sectors in the region, depending on their potentials and availability of resources, whereas, this commitment is not enough to reduce disaster risk.

This section has presented the analysis for USER group interviews. The next section presents the analysis of the Experts group interviews.

#### 5.4.4 Experts Interviews

As mentioned earlier, participants of the group of experts in flash flood field were chosen to include: (a) top management participants from the local concerned authorities (b) academic sector (c) United Nation, non-governmental, communities-based agencies (d) independent experts in flood risk management, aiming to provide a high-level data, could explain the phenomena of flash flooding. In the expert interviews, the interview questions were constructed and coded under four themes and 11 sub-themes (see Table 5.9 for themes and sub-theme and). These themes and sub-themes were coded in NVivo (see Figure 5.8 coding structure for experts)

Table 5.9: Experts themes and sub-themes

Theme	Sub-theme
<b>Flash flood events and effects</b>	(1) Flash flood events (2) Flash flood-prone areas (3) Flash flood effects
<b>Preparedness measures</b>	(1) Prevention measures (2) Contingency plan (3) Awareness
<b>Mitigation measures</b>	(1) Mitigation measures (2) Revision and improvement (3) Assessment
<b>Early warning systems</b>	(1) Early warning systems (2) EWS effectiveness

Nodes		Look for:	Search In	Experts
<ul style="list-style-type: none"> <li>Nodes <ul style="list-style-type: none"> <li>Interviews <ul style="list-style-type: none"> <li>Experts</li> <li>Interviewees</li> <li>Users</li> </ul> </li> <li>Relationships</li> <li>Node Matrices</li> </ul> </li> <li>Sources</li> <li><b>Nodes</b></li> <li>Classifications</li> <li>Collections</li> <li>Queries</li> <li>Reports</li> <li>Models</li> </ul>				
		Experts		
		Name	Sources	References
		Flash flood events and effects	0	0
		Flash Flood Events	10	10
		Flood-Prone Areas	10	30
		Flash Flood Effects	10	20
		Preparedness Measures	0	0
		Prevention Measures	10	10
		Contingency Plan	10	10
		Awareness	10	10
		Mitigation Measures	0	0
		Mitigation measures	10	20
		Revision and improvement	10	10
		Assessment	10	10
		Early warning systems	0	0
		Early Warning Systems	10	40
		EWS effectiveness	10	10

Figure 5.8: Coding structure for Experts

#### 5.4.4.1 Flash Flood Events and effects

The first theme of the experts' interview reveals the flash flood events occurred in the area. Ten experts were asked about these events, flash flood-prone areas, flash flood effects, and the casualties due to these events. The data analysis for these interviews is presented in the next four sub-sections.

##### 5.4.4.1.1 Flash Flood Events

The flash flood events occurred in the study area were discussed in the Users interviews section 5.4.3.1.1 and summarized in Table 5.5. In this section, experts group were asked the same question aiming to get more detailed and high level data. EXPT\_10 has mentioned most of the flash flood events:

*"Recently, two events per year (2013), that occurred from Oct-Apr. I also could remember the other previous floods particularly the floods occurred after 1990s such as: 1991, 1994, 1996, 2001, 2004, 2005, 2009, Jan 2010, Dec 2010, 2011"*

The data collected was repeated by most of interviewees compared with data collected from Users, but again it did cover all flash flood events. Therefore, the researcher will use the flash flood inventory document from local government.

#### 5.4.4.1.2 Flood-Prone Areas

The flood-prone areas are the areas that are within the rainwater drainage streams or low areas. As Expt\_03 mentioned:

*“There are areas prone to flooding by virtue of its presence within the valleys of the rain water drainage, especially the main ones. There are regions and by virtue of urbanisation and lack of rainwater drainage networks suffer the risk of flooding”*

He also mentioned that the fragile and sloping topography of the region contribute to increase risk of flooding:

*“There are other factors contributing to the increased risk of flooding, such as fragile and sloping topography of the region's rocky nature”*

The main valleys in area are as mentioned by Expt\_03:

*“Wadi Siyagh, Wadi Ad Deir, Wadi Numeir, Wadi Mousa, Wadi Turkaniya, Wadi Al Mahfus, Wadi Mataha, Wadi Mudhlim, Wadi Alssadir, Wadi Jelwakh and Wadi Magir”*

These valleys are passing through residential and commercial areas Expt\_03 explained:

*“Most of these valleys pass through residential areas and some others pass through commercial areas”*

These valleys gather and converge in one valley, Expt\_03 added:

*“All these valleys gather and converge in one valley which passes through the tourist areas to expose it to flooding risk”*

The above-mentioned valleys and areas must be considered when designing any warning system for flash floods aimed at reducing floods risk and enhancing Petra Region resilience.

Flood-prone areas are summarised in Table 5.10

Table 5.10: Flood-prone areas – Experts interviews

No.	Flood-prone area
1	Valleys (Wadi's); i.e. Wadi Siyagh, Wadi Ad Deir, Wadi Numeir, Wadi Mousa, Wadi Turkaniya, Wadi Al Mahfus, Wadi Mataha, Wadi Mudhlim, Wadi Alssadir, Wadi Jelwakh and Wadi Magir
2	Valleys boundaries; i.e. residential, commercial, tourist areas
3	Areas with fragile and sloping topography
4	Low areas; i.e. Petra archaeological Park
5	Building close to valleys and water streams; i.e. Hotels, houses and shops in tourist area



#### 5.4.4.1.3 Flash Flood Effects

The third sub-theme in this category is the flash flood effects. As mentioned earlier in the literature review section 2.3.4.1 and also in the Users' interviews in section 5.4.3.2, Petra region was exposed to flash floods that posed major and serious threats to the Region including tourist and local activities as well as the monuments in the archaeological site. In this section, it is intended to review the statements made by Experts group participants about flood effects. Participants were asked two questions (5, 6), see Appendix (C) for these questions.

Expt\_02 considered the upper catchment constitutes a major factor in flood occurrence in the region.

Expt\_03 mentioned that:

*"When it rains, water traces, by gravity, the easiest route forming a surplus in the form of runoff. Valleys are considered as ramps in which water flows easier and quicker collecting and forming large amounts of water, which may rise to torrents or floods when the waterway's ability lacks to discharge more than its capacity"*

Expt\_04, Expt\_05, Expt\_08, Expt\_09, and Expt\_10 explained how valleys constitute as a major factor in flood occurrence in the region:

*"A network of sub-valleys converges in these major valleys which leads to increase the amount of water in these valleys, in addition to the urban and economic development which was a major factor in changing the course of these valleys and reducing their carrying capacity of water, not to mention the confluence of the valleys in the tourist area which leads to a doubling of the amount of water and the occurrence of floods"*

According to Expt\_06 and Expt\_07 while the main valleys (Wadi's) are connected they form a major source of flood:

*"Since all these valleys are connected, the final drainage will become major and affect the flood"*

It is concluded the here bellow the factors lead to the occurrence of floods:

- the network of sub-valleys and major valleys;
- urban expansion and economic development that changed the course of valleys and reduced their carrying capacity of water;
- confluence of the valleys in the tourist area which lead to double the amount of water.

Regarding the casualties or damages left by floods, Expt\_01 stated in general that floods mainly leave casualties or damages to infrastructure, housing, crops, environment and eco-systems, whereas Expt\_02 considered 1963 flood as the deadliest flood which left many dead tourists.

Expt\_03 agreed with Expt\_02 that:

*"Floods mainly leave casualties or damages in the Petra region, for example, the death of 28 tourists and a local guide in 1963, the landslides in the streets, sidewalks and retaining walls, damages in houses and their furniture and gardens"*

Expt\_04 argues that casualties and damages are limited and some casualties occurred in past:

*"I think PDTRA has limited casualties in the last years, whereas, some casualties occurred in the past. Some material damages have happened on some of the old infrastructure with the zone"*

Expt\_04 to Expt\_10 supported that:

*"Some casualties occurred in addition to a wide range of damages in public and private properties. 20 French tourists and local guide in 1963, one from local citizens in 1996, 3 local people"* Said Expt\_04

*"Economic damages, damages of streets, retaining walls, Infrastructure and even Houses sometimes"* Said Expt\_05

*"Economic damages, damages of streets, retaining walls, Infrastructure and even Houses sometimes"* Said Expt\_07

*"Some casualties occurred in addition to a wide range of damages in public and private properties"* Said Expt\_09

It is concluded that floods left casualties especially in 1963, and left many damages in private and public properties, and infrastructure. The data collected here was not saturated enough, therefore, the researcher resorted to the documents that talk about human losses and damages caused by flood.

#### **5.4.4.2 Preparedness Measures**

The second theme of the experts' interview reveals the preparedness measures that have adopted in the study area by local government or local inhabitants. The theme was broken down to three sub-themes: prevention measures, contingency plan, and awareness. The opinion of expert interviewees was taken about these measures, presented and analysed in the next three sub-sections.

##### **5.4.4.2.1 Prevention Measures**

Prevention measures are structural or non-structural. Structural measures: any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems. These measures include dams, floods levies, ocean wave, and evacuation shelters. Non-structural measures: any measure not involving physical construction that uses knowledge, practice or agreement to reduce

risks and impacts, in particular through policies and laws, public awareness raising, training and education. These measures include building codes, land use planning laws and their enforcement, research and assessment, and public awareness programmes (ISDR, 2009a).

Preventive measures must be taken by local governmental institutions or local communities to reduce the floods risk. According to Expt\_01:

*“Measures can be classified as structural and non-structural measures. Structural measures include flood protection/flood defence systems such as levees, storage ponds, pumping stations, or water. Non-structural measures include early warning systems, education, training, drills and exercises”.*

Flood diversion, terracing, afforestation, water harvesting in small dams, preventative construction works in flood prone areas, securing the borders of the valleys to prevent over flooding, and construct obstacles are structural and non-structural measures added by Expt\_02, and Expt\_05:

*“Flood diversion, terracing, afforestation, and water harvesting in small dams”* said Expt\_02

*“Building dams and create pools to collect water in the Valleys, do not constructing works in the Prone areas (Wadi), secure the borders of the Valleys to prevent over flood construct obstacles to reduce the velocity of water, divert water in a controlled manner”* said Expt\_05

Expt\_03 emphasised on the existence of contingency plan as prevention measure to deal with floods that includes:

*“The existence of a contingency plan to deal with the floods includes:*

- a. Readiness of rainwater drainage systems*
- b. The readiness of human and technical resources.*
- c. Awareness on how to deal with the flood.*
- d. Dividing areas of the region depending on the severity and type of risk that may occur due to floods, such as landslides, water raiding houses, the flow of flood waters on the main streets and the resulting risks for cars and commercial sites.*
- e. Evacuating citizens from locations near the valley streams*
- f. Evacuation of tourists and visitors from the archaeological area and prevent the entry of visitors to the area during flooding*
- g. Coordination with other actors such as civil defence and public security, hospitals, electricity and water authorities in addition to petrol stations and sites to provide citizens with the major needs such as food”*

Expt\_04 added that applying risk sensitive land use planning in flood prone areas and communicating the risk with partners are non-structural measures that help to reduce flood risks:

*“Applying Risk sensitive land use planning in flood prone areas and communicating the risk with partners so it is understood and accepted. Plans and activities are introduced to deal with this risk proactively”*

Expt\_06 and Expt\_07 proposed many measures; structural and non-structural, to prevent and reduce flood risks. He emphasised on the early warning systems, planning, training, regulation, and implementing protective systems.

*“Permanent monitoring of the risk of flooding, setting up one or several information and flood warning centres for the population, issuing regulations banning building, residing in, and access to identified risk zones and implementing specific protective systems such as alarm signals, building and developing infrastructure that will prevent, avoid or limit floods and protect the population, planning the evacuation of the population likely to be at risk, and instructing them on how to behave in case of a flood and Forming well trained and equipped management and rescue teams”* said Expt\_06

*“Early warning sign by local government and DRR Msg’s provided in schools to avoid or mitigate the impact of risks”* said Expt\_07

Expt\_8, Expt\_9, and Expt\_10 are obviously adopting preventive measures in flood time. They also emphasised on setting up early warning systems:

*“Preventive measures have to be taken to reduce the floods risk are: (1) Setup an early warning system for floods (2) Buildings construction out of floodplains (3) spend money in flood defences (4) restore valleys to their original capacities and natural courses (5) build small dams in the major valleys to reduce water flowing velocity”*

Finally, it is concluded that prevention measures; that must be adopted to reduce flood risks in study, are structural and non-structural measures as shown in the Table 5.11:

Table 5.11: structural and non-structural measures

Structural Measures	Non-structural Measures
Protection/flood defence system such as: levees, storage ponds, pumping stations, water canals	Early warning systems
Flood diversion	Education
Terracing	Training
Afforestation	Drills and exercises
Water harvesting in small dams, pools, valleys	Contingency plan
Secure valleys’ borders	Awareness
Construct obstacles	Sensitive risk land use planning
Developing infrastructure to prevent, avoid or limit floods	Communicating risk with partners by alarms signals, or messages
Restore valleys to their natural courses	Land use planning; banning construction in floodplains
Invest in flood defences	Monitoring flood risks

#### 5.4.4.2.2 Contingency Plan

The second sub-theme of preparedness measures theme is concerning the contingency plan for local government (Petra Authority) and the coordination with concerned parties to reduce flood risk within this plan.

Sharing data and information, organising joint awareness campaigns, undertaking exercises and drills, and developing EWS, are proposed measures by Expt\_01 and Expt\_05 to maintain coordination between concerned parties in the study area to reduce flood risk:

*“Sharing data and information; organizing joint awareness campaigns; undertaking exercises and drills; developing an early warning system”* said Expt\_01.

*“Drills and Exercises should be done to examine the level of coordination between the different parties, Awareness campaigns for the local Communities, Evacuation plans and practicing it always”* said Expt\_05.

Expt\_03, Expt\_04, Expt\_08, Expt\_09, and Expt\_10 emphasised on the availability of contingency plan in local government, the coordination within concerned parties in study area, and the Emergency Operation Centre (EOC) which is activated in flood time:

*“There is a continuous coordination with the Civil Defence, the electricity company and the water authority in the governorate, in addition to private-sector owners of heavy machinery such as loader and cranes. There is also Emergency Operation Centre (EOC) at Petra governorate and emergency committee headed by Governor. In EOC, committee reviews and updates the emergency plan as new data before winter season, taking in account all new variables and lessons learned from previous events in the plan to improve outcomes”* said Expt\_03.

*“Petra Region Authority has an emergency room as well as the technical teams and necessary equipment and machinery to deal with the disaster. This room is activated in case of the disaster, such as flood. The disaster is managed through this room and in coordination with the Civil Defence and the Governorate of Petra. Moreover, the authority communicates with the owners of heavy machinery from the private sector to provide assistance when needed”* said Expt\_09.

Expt\_06 consider EWS as an important tool for all responders for coordinating the efforts:

*“It should be known that the effectiveness operational EWS will serve as an important tool for all responders (PDTRA, Ministry of Interior, Civil Defence and others) for coordinating the efforts and have lead time for responding, so regular consultations and discussions need to be maintained”*

Expt\_07 assumed that coordination should be of annual bases and include local community organisations:

*“This should be of annual bases and in close cooperation and coordination with Jordan Civil Defence(JCD) and other relevant stakeholders including the local community organisations”*

It is concluded that PDTRA, within its contingency plan, coordinates with concerned parties to reduce flood risk by:

- Sharing data and information.
- Organizing joint awareness campaigns.
- Undertaking exercises and drills.
- Developing an early warning system
- Reviewing and updating emergency plan
- Lessons learned
- Evacuation plans
- Providing potential assistance

#### **5.4.4.2.3 Awareness**

Awareness is the extent of common knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards. Public awareness is a key factor in effective disaster risk reduction. Its development is pursued, for example, through the development and dissemination of information through media and educational channels, the establishment of information centres, networks, and community or participation actions, and advocacy by senior public officials and community leaders (ISDR, 2009a).

Awareness campaigns are prevention measures that are required to raise the knowledge of the local communities, local governmental institutions, private sector, and vulnerable people to reduce exposure to flood risk. Awareness; stated by interviewees in previous section, should coordinated with concerned parties within the contingency plan. Therefore, this sub-theme has focused in how local communities could be aware of the actions that should act in case of flood.

Expt\_01, Expt\_02, and Expt\_05 stated that locals could be aware by:

*“Awareness campaigns; Participatory processes; drills and exercises; community engagement”*  
said Expt\_01

*“Through training and public awareness”* said Expt\_02

*“The locals could be aware of actions that have to take in case of flood by conducting awareness Campaigns, training on safety and security”* said Expt\_05

Some interviewees such Expt\_03, Expt\_04, and Expt\_06 to Expt\_10 added: workshops, lectures, media and social media, neighbourhood disaster volunteers, participation in decision making and consultation with all concerned stakeholders.

*“Workshops, lectures, media, social media, and neighbourhood volunteer teams are considered important tools to link with local communities to raise awareness and knowledge among the citizens at various levels to deal with the flooding risk”* said Expt\_03

*“The locals could be aware of actions that have to take in case of flood by conducting awareness campaign and training. Participatory processes; drills and exercises; community engagement”* said Expt\_08

Finally, it is concluded that concerned parties can raise local communities’ awareness, in terms of actions they need to do in case of floods, through the following:

- Awareness campaigns
- Participatory processes
- Drills and exercises
- Community engagement
- Training and workshops
- Lectures
- Media and social media
- Neighbourhood disaster volunteers
- Participation in decision making
- Consultation with all concerned stakeholders.

#### **5.4.4.3 Mitigation measures**

The third theme in experts’ interviews was mitigation measures which adopted by local authorities and local inhabitants, the periodic review of these measures and improvement and the authorities involved in the revision and improvement, and finally the assessment process of damages due flooding. In the next sub-sections, the interviews data concerning these measures are analysed in next sections.

##### **5.4.4.3.1 Mitigation Measures**

Mitigation is the lessening or limitation of the adverse impacts of hazards and related disasters. The adverse impacts of hazards often cannot be prevented fully, but their scale or severity can be substantially reduced by various strategies and actions. Mitigation measures encompass

engineering techniques, hazard-resistant construction ,improved environmental policies, and public awareness (ISDR, 2009a).

Structural mitigation: any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems. Non-structural mitigation: any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education (ISDR, 2009a).

As previously mentioned, the mitigation measures include both measures adopted by local government and local communities.

According to Expt\_01, the local government has adopted a combination of structural and non-structural measures which is so called “holistic” approach, whereas the people can do that by preparing and educating themselves.

Expt\_03 stated that local government has adopted many non-structural mitigation measures:

*“Petra Region Authority adopted many measures based on a scientific method of monitoring the storms causing flooding before they happen through accurate weather forecasts as well as monitoring the amount of rainfall by weather stations in addition to the preparation of the prior plans to deal with these risks, such as contingency plans, preparation”*

And structural mitigation measures:

*“Processing infrastructure such as rainwater drainage systems, retaining walls, establishment of small check dams in the main valleys to mitigate flood’s intensity”*

Whilst local citizens depend to a great extend at PDTRA in reducing floods risks:

*“Citizens in Petra Region depend to a great extent on the Petra Region Authority in reducing flood risk, and they change the flood course during formation from their homes. The others build walls of brick or concrete to keep out floods from their homes into the street, exacerbating things and increases the amount of water to affect neighbouring homes”* said Expt\_03

Expt\_04 mentioned that local government adopted non-structural measures such as:

*“(1) Defined floodplains (2) Modified the building codes and regulation to prevent building or investment next to major valleys or floodplains (3) modified warning system for flash flood (4) conduct workshops in terms of awareness for floods”*

And structural measures like:

*“(5) rehabilitate rainwater channels before raining season (6) construction of retaining wall to protect road and both private and public properties”*

For the local citizens:



*“People are asked to secure the entries of their properties against water rising and also informed about the risk and the safety measures they have to take before during and after the flash flood”*  
said Expt\_04

Retaining walls, culverts, and diverting water to valleys are other measures added by Expt\_05 as governmental measures, whereas the local citizens adopted some other measures. He added that:

*“Some of the local people adopted some measure to prevent themselves and their properties from floods such as establishing small rain water channels around their properties, whereas, most of the local people over rely on the regional measures adopted by the local authorities”*

According to Expt\_06, building codes, floodplains, awareness, contingency planning, emergency teams, rehabilitate rainwater systems, and retaining walls are measures adopted by PDTRA as local government. Divergent channels, small scale dams and plantation are measures adopted by local communities.

Expt\_07 concentrated at governmental adopted measures that are:

*“Developed early warning for tourism and local people, conduct training and awareness for local community how to deal with such event and mitigate the impact, develop awareness material for different levels and ages including children, women and employees”*

And advised people to:

*“Follow the instruction proved by the local government, some of them already create channels for water to avoid floods in their properties”*

Expt\_08, Expt\_09, and Expt\_10 almost summarised all above interviewees’ opinions for the governmental measures as:

*“(1) Defined floodplains (2) Modified the building codes and regulation to prevent building or investment next to major valleys or floodplains (3) modified warning system for flash flood (4) conduct workshops in terms of awareness for floods. (5) rehabilitate rainwater channels before raining season (6) construction of retaining wall to protect road and both private and public properties”* said Expt\_08

For the local people, they stated that:

*“(1) Defined floodplains (2) Modified the building codes and regulation to prevent building or investment next to major valleys or floodplains (3) modified warning system for flash flood (4) conduct workshops in terms of awareness for floods. (5) rehabilitate rainwater channels before raining season (6) construction of retaining wall to protect road and both private and public properties”* said Expt\_10

Finally, the mitigation measures adopted by local government are structural and non-structural, and could be summarised as in Table 5.12.

Table 5.12: Mitigation measures adopted by local government and local communities

Structural measures	Non- Structural measures
<b>Local government</b>	
Rehabilitate rainwater channels and culverts	Monitoring floods
Small check dams	Floodplains
Retaining walls	Building codes and regulation
Awareness	Modifying warning system for flash flood
Contingency plan	Workshops and training
Emergency teams	
Retaining wall	
<b>Local communities</b>	
Terracing	
Small dams	
Small rainwater channels	

#### 5.4.4.3.2 Revision and Improvement

The second sub-theme of mitigation measures theme is: revision and improvement. The revision and improvement process should be implemented after each flood event or as appropriately needed. Moreover, involved parties are required to review their measures jointly. The interviewees were asked if there was a periodic review for mitigation measures and improvement as appropriately needed, the involved authorities in review and improvement, and if there were joined activities between different authorities and agencies.

Expt\_03 and Expt\_04 stated that there is an annual or periodic review and improvement:

*“There is periodic review for these measures and improvement after each flood event and as appropriate need. The authorities involved in this review includes Petra Region Authority, Civil Defence, Petra Governorate, Water and Electricity Authorities”* said Expt\_05

*“Yes, the measures and improvement in terms of flood prevention are reviewed annually and when over needed. The principle of build back better is used by Petra authority in the recovery phase to avoid feature expected damages. Activities are jointly implement with concerned parties in the region”* said Expt\_04

Expt\_05, Expt\_06 and Expt\_07 stated that there is review but need more work:

*“Yes, but more work still needed”* said Expt\_05

*“Not really, since still these authorities working on ad hoc basis”* said Expt\_06

*“I think there should be a system where the local authority can monitor and evaluate their measures”* said Expt\_07

Expt\_08, Expt\_09, and Expt\_10 stated that the review for the measures is mainly implemented annually and whenever needed. Moreover, PDTRA is adopting the principle of build back better in its recovery phase after floods or any other disaster. Petra Authority works side by side with Petra governorate.

Finally, the revision and improvement are implemented annually and whenever needed. Moreover, PDTRA is adopting the principle of build back better in its recovery phase after floods or any other disaster. Petra Authority works side by side with Petra governorate.

#### **5.4.4.3.3 Assessment**

The third sub-theme is the assessment of the damages occurred due to flooding. Estimated losses from flooding could be quite complicated stated Expt\_01. He added:

*“It involves housing, infrastructure, crops and agriculture, but also long terms damages to the eco-system, livelihoods, loss of income (from tourism for example) and other potential liabilities”*

Expt\_03 mentioned that the assessment of the damages due to flooding should include: (1) the causes of damages, their nature and estimated rehabilitation cost; (2) Damage estimation cost of private property including houses, buildings, land loss, crops and livestock.

Expt\_04, Expt\_05, Expt\_09, and Expt\_10 stated that PDTRA should assess the damages due to flooding by visual observation on the ground via a committee of engineers to report these damages to their top management to decide the action that should be taken.

Expt\_06 and Expt\_08 also supported Expt\_04, Expt\_05, Expt\_09, and Expt\_10:

*“Whether by visual observations or reports based on (on-ground) assessment, after documenting these damages, the authority compensates the people if there are no remarks on the permissions for construction and as per the available budget”*

PDTRA should assess the damages on regular bases using different available tools such as rapid assessment, field visits, interviews with affected people side walk, said Expt\_07

It is then concluded that PDTRA usually assesses the damages due to flooding by visual observation on the ground via a committee of engineers which reports to the top management to decide on the reconstruction of the damages occurred. The assessment involves housing, infrastructure, crops and agriculture, but also long terms damages to the eco-system, livelihoods, loss of income (from

tourism for example) and other potential liabilities. PDTRA assesses the damages on regular bases using different available tools such as rapid assessment, field visits, interviews with affected people side walk.

#### **5.4.4.4 Early Warning Systems**

The last theme in the expert interviews is the Early Warning Systems. This theme consists of two sub-themes: Early Warning Systems and EWS Effectiveness.

##### **5.4.4.4.1 Early Warning Systems**

The first sub-theme is the EWS, in which the interviewees were asked to define EWS from their point views, how soon should the warning be received for it to be meaningful, and the factors involved in the warning.

Early Warning System (EWS) is “the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss” (ISDR, 2009a, p. 12).

This definition encompasses the range of factors necessary to achieve effective responses to warnings. A people-centred early warning system necessarily comprises four key elements: knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received. The expression “end-to-end warning system” is also used to emphasize that warning systems need to span all steps from hazard detection through to community response (ISDR, 2009a, p. 12).

Expt\_01 to Expt\_10 defined the EWS as:

*“a mechanism composed of instrumentation measurements and an alert system that gives the population enough time to evacuate in case of an event”* said Expt\_01

*“EWS is a necessary system using rainfall forecast and radar images”* said Expt\_02

*“It is a computerized system that operates based on spatial sensors in the main valleys and peaks of the surrounding mountain of the city. These sensors measure the amount of precipitation and measure the height of the water and runoff in the valleys. Using a special formula or model and upon the arrival of threshold limit measurements assigned in the model”* said Expt\_03

*“EWS is a tool used to receive forecast or real-time data from rain gauges to process these data and calculate the runoff that might leads to flood then issue warning to target parties to take an action. An effective EWS needs to involve the local community at risk, facilitate awareness of*

*risk, disseminate alerts and warning. A complete and effective EWS supports four main functions: risk analysis, monitoring and warning, dissemination and communication, and a response capability” said Expt\_04*

*“EWS is a system that issues forecasts upon which is acted, its primary objectives are to increase the preparedness of the authorities and population for flash floods, to plan emergency and risk communication procedures and to strengthen the institutional capacity in order to effectively operate an EWS and communicate the warning” said Expt\_06*

*“It is a system to warn people time ahead at least 4 hours before flood occur and aim to avoid damage and mitigate the impact of the flood such as give people, local authority time to evacuate properly and leave the risk (flood) area” said Expt\_07*

Regarding the time that EWS should provide to be meaningful, Expt\_01 stated that EWS should provide enough time for the public to organize the and start evacuation.

Expt\_03 added that:

*“the system alerts the concerned authorities or local communities by issuing an audio readable warning of an approaching flood. This warning will call for caution in advance and implement evacuation plans previously prepared”*

The warning should be received before 2-4 hours to be meaningful as stated by Expt\_04, Expt\_05, Expt\_08, Expt\_09, and Expt\_10

EWS should give people, local authority enough time to evacuate properly and leave the risk (flood) area as proposed by Expt\_07

Expt\_01, Expt\_08, and Expt\_10 considered the factors involved in the lead time as the parameters of the flood hazard, the nature of the population that is at risk, the environmental conditions, density, etc.

The main component of the EWS are:

*“Instrumentation, tracking, alert, evacuation, sheltering, assessment and return” said Expt\_01*

*“Rainfall forecast, radar images, climate stations, rainfall-runoff forecasting model, alarm system” said Expt\_02*

Expt\_03, Expt\_04, Expt\_09 and Expt\_10 stated that the main component of the EWS are:

- Rain gauges to measure the amount of rainfall and intensity of precipitation.
- Flow gauges to measure the height of water runoff levels in the valleys
- Alert system (voice or message)
- Communication control unit

- Receiver and transmitter
- Computer and Software to process the measured or predicted values through a special model (i.e. rainfall-runoff)

Expt\_05 summarised these component as: stations, centre of monitoring, alarm system

Expt\_06 considered flood wave modelling, assessment model performance, simulating scenarios, strategy for issuing warning and responding to warning, and technical capacity building as EWS components in addition to Telemetered rain gauges and Rainfall forecasting.

Expt\_07 talked about the process of EWS which is:

*“Identify, assess risks, monitor and warning services, dissemination and right communication and effective response capacity including contingency, preparedness response, and recovery plan”*

EWS that might be installed anywhere, according to Expt\_01 to Expt\_10, it may target people at risk such as:

- Local communities;
- Local government and local relevant authorities
- Civil Defence
- Economic and tourist sectors

Some of the interviewees proposed that EWS should be directed to local government only such as Expt\_02 who stated that:

*“EWS should be directed to Civil Defence and local relevant authorities”*

Expt\_03 said:

*“The system should be directed to the government only, where it takes measures to reduce the risk of flooding without confusion or panic among the citizens, whereas, on the optimal situation, Warnings must reach those at risk. Clear messages containing simple, useful information are critical to enable proper responses that will help safeguard lives and livelihoods”*

Expt\_04:

*“EWS should be directed to local governmental institutions that concern about flash flood”*

Some other like Expt\_08, Expt\_09, and Expt\_10 argued that Local communities depend on responding to floods at the local government, the EWS should then be directed to local government who then disseminate alerts to local communities.

The last part of this sub-theme is the current EWS's related to floods in study area. Expt\_03 answered by:

*"Early warning systems related to floods have never been installed in the Petra region. However, concerned authorities in the region deal with each rain storm according to its intensity at the time. Also, these authorities depend on the forecasts of the Meteorological Department and eyewitnesses' data in the region"*

Expt\_04, Expt\_05, Expt\_08, Expt\_09 explained the local flood warning systems (LFWS) that may be locally installed which based a rainfall and river gauges, and flash flood guidance systems which are a combination of rain gauges, remote sensing data, and hydrologic models and rainfall forecast.

Expt\_06 added that:

*"In the country, no EWS, but in the region, there is a system implemented in the Sinai Peninsula (Egypt)"*

Expt\_07 emphasised on the existing DRR structure for warning dissemination rather than a parallel system, utilising volunteers as communication agents:

*"Strengthening the existing DRR structure for warning dissemination rather than a parallel system, utilising volunteers as communication agents. Build a team of at the local level that can assist in the warning dissemination and response, utilising local information centres. Importance of linking to non-disaster institutions already available at the local level and training these so they can be activated during the disaster period, Voice Message Broadcast (VMB) communication tool for early warning to people including the most vulnerable, governmental officials, NGOs and selected volunteers. Short messaging service (SMS). Collect water level readings and disseminate by trained local people to the national flood warning centre using SMS, technical forecasting and early warning training for NGO partners and selected community volunteers"*

Finally, it is concluded that:

- EWS is a tool used to receive forecast or real-time data from rain gauges to process these data in order to calculate the runoff that might lead to flood then issue warnings to target parties to take an action. An effective EWS needs to involve the local community at risk, facilitate awareness of risk, disseminate alerts and warning. A complete and effective EWS supports four main functions: risk analysis, monitoring and warning, dissemination and communication, and a response capability. This finding complies with the community-based early warning systems suggested by (IFRC, 2012; Phaiju *et al.*, 2010a) in section 2.5.1. Moreover, UNEP (2012) highlighted the aspects of early warning systems as: risk analysis; monitoring and predicting location and intensity of the disaster; communicating alerts to authorities and to those

potentially affected; and responding to the disaster. The early warning system has to address all these aspects

- EWS components are: Rain gauges, flowmeters, warning system, communication systems to send and receive data, computer and software to analyse data, rainfall-runoff model. Some of these elements have appeared in the early warning systems that were presented in literature review in sections 2.5.2 and 2.5.3
- EWS should be directed to local communities, local government, economic, tourist sectors, and risk and alerts then should be disseminated to local communities and these sectors. whereas some argued that EWS should be directed to local governmental institutions that concern about flash flood.
- Early warning systems related to floods have never been installed in the Petra region, but in the Arab region, there is a system implemented in the Sinai Peninsula (Egypt). However, concerned authorities in the region deal with each rain storm according to its intensity at the time. Also, these authorities depend on the forecasts of the Meteorological Department and eyewitnesses' data in the region. Local flood warning systems (LFWS) which based a rainfall and river gauges, and flash flood guidance systems which are a combination of rain gauges, remote sensing data, and hydrologic models and rainfall forecast.

#### **5.4.4.4.2 EWS Effectiveness**

The second sub-theme of early warning systems theme is the effectiveness of the early warning systems. In this sub-theme, the interviewees were asked how an EWS would be effective systems and help mitigating flood impacts.

Reliable forecast or measurements, clear threshold for warning and alert, excellent system of communication, preparedness and drills, are the factors stated by Expt\_01 and Expt\_08 that accomplish EWS effectiveness. Whilst Expt\_02 considered it effective if it can issue at least 6 hours advanced warning time.

Expt\_03 believed that EWS would be effective system and helps mitigating floods impacts when the four key elements are available: (1) Risk knowledge, i.e. risk assessment, vulnerability and exposure; (2) Technical monitoring and warning service; (3) Communication and dissemination of warnings; and (4) Community response capability.

Expt\_04, Expt\_09, and Expt\_10 considered the involvement of the local community at risk as a requirement to EWS to be effective and:



*“A complete and effective EWS supports four main functions: risk analysis, monitoring and warning, dissemination and communication, and a response capability”*

Expt\_05 considered EWS effective if it gives time to implement an evacuation people at risk if needed.

Expt\_06 stated that:

*“Warnings can be issued based on pre-defined thresholds of meteorological observations and/or forecasts, runoff, flow, flood depth or flood extent”*

Therefore, crucial for the operational use of EWS, are the steps taken between the issuing of a warning and the start of actual actions on the ground. The period between the warning and the actual event is called the lead time. During this lead time, local communities and responders can act as per the plans set based on participatory approach.

Expt\_07 consider the EWS an effective:

*“If it follows and apply the main component the EWS. And train other how to respond and communicate well with it. What they should do when it is activated”*

It is concluded that EWS is an effective system if:

- EWS is an effective system if it has: (1) Reliable forecast or measurements (2) clear threshold for warning and alert (3) excellent system of communication (4) preparedness and drills.
- EWS would be an effective system and helps mitigating floods impacts when the four key elements are available: (1) Risk knowledge, i.e. risk assessment, vulnerability and exposure; (2) Technical monitoring and warning service; (3) Communication and dissemination of warnings; and (4) Community response capability.
- can do at least 6-hr advanced warning time.
- An effective EWS needs to involve the local community at risk, facilitate awareness of risk, disseminate alerts and warning. A complete and effective EWS supports four main functions: risk analysis, monitoring and warning, dissemination and communication, and a response capability.
- It gives time to implement an evacuation if needed.
- It gives enough lead time to enable responders to act as per plans set based on participatory approach.
- If it follows and applies the main component the EWS, trains others how to respond and communicate well with it, and what they should do when it is activated.
- Reliable forecast or measurements, clear threshold for warning and alert; excellent system of

communication; preparedness and drills.

## 5.5 Documents

The documents collected are available as statistical data from many Ministries and authorities. These documents are: flood inventory, precipitation, number of fatalities per flood and overall fatalities, amount of damage caused by flood, time and period of flood...etc.

### 5.5.1 Feasibility study for Flash Flood

One of the document that is available in Petra Development & Tourism Region Authority (PDTRA) is "*Feasibility study for Flash Flood, Landslide, and Rock Fall Assessment in, Petra, Jordan, 2012*".

- This study has identified the four main hazards that threaten Petra Region. These hazards are flash floods, landslides, rock fall and earthquakes, and that is a good benefit from this study to identify the main hazards in the study area.
- The second benefit, the study also has determined the available rain gauges (weather stations) in the area and the neighbourhood areas that are limited and only allow to measure the total rainfall volume, whilst, monthly, daily and hourly rainfall time series are ordered from Jordanian Meteorological Department (JMD) from the start of measurement (see Table 5.13 which shows the existing weather stations in the area and neighbourhood areas)Table 5.13Measurement lack accuracy, because the available weather station in the area is located in Wadi Mousa city in Petra Region and collects only the daily rainfall, therefore, the rainfall is only considered on one location within an area of 800 km<sup>2</sup>. Rainfall is also considered at a certain elevation whereas area's elevation is ranging from 800 m- 1580 m. Moreover, the neighbourhood area that are far away from Petra region (the closest one is Shoubak weather station 25 km). This is one of limitations to the use of rainfall-runoff models.
- The document refers to the existence of a single weather station in the region (Wadi Mousa weather station) (see Table 5.13)Table 5.13Accurate knowledge of the spatial and temporal distribution of rainfall is essential for flash flood early warning systems (Hoedjes *et al.*, 2014). This station will not be able to record the accurate distribution of rainfall in the region due to variation in topography, and the amount of precipitation readings would be unreliable and cannot be generalized to rest of the region. Therefore, it is crucial to establish other stations in the region achieve accurate distribution of rainfall aiming to predict the exposed places to flash floods.

Table 5.13: Existing rain gauges in South Jordan and their locations

Location	Latitude (North)	Longitude (East)	Elevation (masl)	Start date (monthly)	Start date (daily)	Distance to Petra
Aqaba Int'l Airport	29 36 15	035 01 07	51	Jan 1946	01-03-1956	125km
Ma'an	30 10 14	035 45 54	1069	Jan 1938	01-09-1959	35km
Shoubak	30 30 38	035 31 50	1365	Jan 1938	01-07-1960	28km
Wadi Mousa	30 19 03	035 28 14	1115	Jan 1976	01-05-1984	0km

Source: PDTRA Document

### 5.5.2 Inventory of flash flood events

Another benefit of PDTRA Study is the inventory of flash flood events. Inventory is made of the historic flash floods in the Wadi Mousa catchment, including Petra based on the information from witnesses, researchers, or internet (Appendix C). According to this study, Petra has encountered many flash floods from 1963-2013 caused many fatalities such as in 1963 event. The water depth reached about 10m in some areas of Siq. Many of the flash floods occurred in April (not a rainy month) especially, 1963, 1994, 2001 and 2011. Other flash floods occurred during the rainy months November, December, January, February, and March. However, information about past floods (paleo floods) can provide an unprecedented data set that is essential to understanding the real behaviour of extreme events, magnitude and frequency, as well as the relation to hydroclimatic variability and possible global climatic change (Al-Qudah, 2011). The second objective of this research is “to review the incident reports of previous flash flood events in Petra Region and how they affect the study area”.

### 5.5.3 Integrated Risk Assessment

This document mainly talks about the assessing the main four risks threatening Petra region. One of these risks is flash flood. in this document, the main Wadi's (valleys) in the study area were defined as following:

- Wadi Magir: Passes through residential areas
- Wadi Jelwakh: Passes through residential areas
- Wadi Khalil: Passes through residential and economic areas
- Wadi Alssadir: Passes through residential and economic areas
- Wadi Mousa: Passes through residential and tourism areas

This finding is very important, because it identifies the main streams exposed to flash floods, however, the areas that these streams are passing through that are also exposed to flash flood. Conceptual scheme of the major Wad's and sub-Wadis as shown in Figure 5.6, The GIS map for

Wadis (major and sub Wadis) as shown in Figure 5.9. These Wadis are meeting at the tourism area (circle) and then continue to archaeological site (arrow).



Figure 5.9: GIS map for Wadis and sub Wadis in Petra Region

### Part 3: Findings

#### 5.6 Findings

Twenty semi-structured interviews; ten experts and ten users, were conducted in the second stage of data collection. The data was analysed using content analysis. Several pieces of information were revealed through data analysis for both interviews; experts and users, such as:

- Flood events: events, prone areas
- Flood impacts: effects, impacts and casualties
- Preparedness: prevention measures, independent measures, risk knowledge, training and awareness, and contingency plan
- Mitigation: measures, revision and improvement, and assessment
- Local authorities' roles: cooperation and coordination, and training
- Early warning systems: EWS's and effectiveness

Some respondents highlighted the non-structural and structural mitigation and prevention measures adopted by local government and local communities in the study area, the coordination between concerned parties, the contingency plan and its assessment and improvement for the PDTRA, the EWS and when it would be an effective system, the need for awareness and training for local communities. The other important issue highlighted by respondents, is that local communities

consider the meteorological information about floods that they receive through Jordanian Meteorological department (JMD) or any other source, is not accurate or reliable because of the many mistakes that occurred in the forecasts; this information should be known and easy to access for all inhabitants in the area especially in the rainy seasons.

Some limitations hinder the implementation of the concept of local community-centred EWS because local communities essentially lean at the local government in the reducing flash flood risk, the lack of risk knowledge, lack of available tools to prevent or mitigate the flash flood impacts, and weak coordination between local communities and local governments in terms of reducing flood risk.

This will lead the researcher to design the guidance to be directed to local governments, considering the possibility of communicating with local communities and inform them of the risks they may be exposed, to be able to undertake any efforts that will reduce their risk exposure and thus reduce the flood impacts on their lives and properties.

### **5.6.1 Users' interviews**

#### **5.6.1.1 Flash flood events**

##### **5.6.1.1.1 Flash flood events.**

After reviewing all interviews about flash floods events, it is found that they occurred as shown in (Table 5.5) and some of these events happened when the tourism was at its peak which posed economic impacts at the local communities and at local authorities which benefit from tourism, and when the tourism was not at its peak which leaves economic impacts but less than when it is at its peak. The occurrence of these events has left many damages in private and public properties besides the death of many people.

##### **5.6.1.1.2 Flash flood-prone areas.**

The flood-prone areas are: (1) Valleys (Wadi's) and their boundaries (2) Water streams (3) Low areas (4) Buildings close to valleys and water streams (see Table 5.6 ). The reason after considering these areas as flood-prone area is due to the steep nature of the Petra region which leads to larger amount of collected rain water (catchments).

### **5.6.1.2 Flash flood impacts**

#### **5.6.1.2.1 Effects of floods**

Flash flood events have left many effects on the tourism, economic, and social sectors, besides the effects at the infrastructure in study area.

#### **5.6.1.2.2 Impacts of floods**

There were severe impacts on infrastructure such as roads, retaining walls, sewage system, water and electricity networks, rainwater drainage systems, and irrigation canals, besides the impacts on the local community properties such as houses, vehicles, furniture, and electrical appliances (see Table 5.7).

#### **5.6.1.2.3 Casualties**

It is concluded that there were casualties due to flash floods in Petra region. The most well-known are the death of 20-29 French tourist in the entrance (Siq) of archaeological area in 1963. The floods of 1996 and 2001 led to the death of one and three residents respectively. The reason behind casualties in 1963 was the absence of dam or barrier at the entrance of Petra's Siq (see Table 5.8).

### **5.6.1.3 Local Community preparedness**

#### **5.6.1.3.1 Independent measures**

The procedure that might be followed in case of floods is well known by local citizens but could be enhanced by workshops and awareness campaigns. Most of citizens have undertaken independent measures to protect themselves and their properties from floods.

#### **5.6.1.3.2 Risk knowledge**

Most of local community seeks information from media and weather forecast that mainly depends on the Jordan Meteorological Department (JMD), but they claim the information is not accurate enough, inadequate, and limited. They are also not satisfied with this information. Whereas some of the local community members seek information via Petra Authority or friends who are close to flood areas.

For the adjustment that may be needed in terms of the availability of information about floods, the data should be available and easy to access for inhabitants in the area in general and for whom is at risk in particular. Data could also be provided through websites of the local authorities, social media, and billboards at most accessed place in the region, and at information windows in visitor centre for the Petra tourists.

#### **5.6.1.3.3 Training and awareness**

Local concerned parties in disaster risk reduction should have a comprehensive training and awareness programmes to local communities in general and to those at risk and emergency teams whom in charge with flash flood in particular, and these programmes have to be implemented periodically.

#### **5.6.1.4 Local Authorities' Roles**

##### **5.6.1.4.1 Cooperation and coordination**

There is coordination and cooperation between governmental institutions in terms of flash flood risk reduction, but limited with local community agencies.

##### **5.6.1.4.2 Training**

Training and awareness processes should be implemented by the parties that deal with flash flood events, and they should hire qualified trainer with adequate information and experience to deliver this information to local community members and any other sectors whom require this training.

##### **5.6.1.4.3 Commitment**

The commitment of local authorities acceptable to some extent depending in the available resources in these authorities such as: equipment, sufficient number and appropriate type of machinery, and qualified teams to deal with flash flood events. Therefore, the local concerned authorities need to deal with flash flood events effectively and show more commitment.

The overall findings from users' interviews data analysis about the role of local authorities in terms of disaster risk reduction indicate that:

- There is some coordination and cooperation between the local authorities concerned with reducing disaster risk, while it is almost non-existent with the local community institutions.
- Training and public awareness, which are the responsibility of the Civil Defence and the authority of Petra, is considered inadequate and implemented in a limited way in the study area.

Local authorities show some commitment to the local community and other sectors in the region, according to their potentials and availability of resources, whereas, this commitment is not enough to reduce disaster risk.

## 5.6.2 Experts' interviews

### 5.6.2.1 Flash flood events and effects

#### 5.6.2.1.1 Flash flood events

The data collected was repeated by most of the interviewees compared with data collected from Users, but again it did cover all flash flood events (see Table 5.5).

#### 5.6.2.1.2 Flood-prone areas

The flood-prone areas are: (1) Valleys (Wadi's) and their boundaries (2) Water streams (3) Low areas (4) Buildings close to valleys and water streams (see Table 5.10).

#### 5.6.2.1.3 Flash flood effects

Floods left casualties especially in 1963, and left many damages in private and public properties, and infrastructure. The data collected here was not saturated enough, therefore, researcher resorted to the documents that talk about human losses and damages caused by flood.

### 5.6.2.2 Preparedness measures

#### 5.6.2.2.1 Prevention measures

Prevention measures; that must be adopted to reduce flood risks in the study are structural and non-structural measures (see Table 5.14 )

Table 5.14: Prevention measures to adopt by local government

Structural Measures	Non-structural Measures
Protection/flood defence system such as: Levees, storage ponds, pumping stations, water canals	Invest in flood defences
Flood diversion and terracing	Early warning systems
Afforestation	Training, awareness, drills and exercises
Water harvesting in small dams, pools, valleys	Contingency plan
Secure valleys' borders and construct obstacles	Land use planning and sensitive risk land use planning
Developing infrastructure	Risk dissemination
Restore valleys to their natural courses	Monitoring flood risks

#### 5.6.2.2.2 Contingency plan

PDTRA; within its contingency plan, coordinates with concerned parties to reduce flood risk by:



- Sharing data and information.
- Organizing joint awareness campaigns.
- Undertaking exercises and drills.
- Developing an early warning system
- Reviewing and updating emergency plan
- Lessons learned
- Evacuation plans
- Providing potential assistance

#### **5.6.2.2.3 Awareness**

Concerned parties can raise local communities' awareness; in terms of actions they need to do in case of floods, through the following:

- Awareness campaigns
- Participatory processes
- Drills and exercises
- Community engagement
- Training, workshops and lectures
- Media and social media
- Neighbourhood disaster volunteers
- Participation in decision making
- Consultation with all concerned stakeholders

#### **5.6.2.3 Mitigation measures**

##### **5.6.2.3.1 Mitigation measures**

The mitigation measures adopted by local government are structural and non-structural, and could be summarised as shown in Table 5.15:

Table 5.15: Mitigation measure to adopt by local government

<b>Structural Measures</b>	<b>Non-structural Measures</b>
Rehabilitate rainwater channels and culverts	Monitoring floods
Small check dams	Floodplains
Retaining walls	Building codes and regulation
Construction of retaining wall to protect road	Modify warning system for flash flood

and both private and public properties	
Terracing	Awareness programmes
Small dams	Contingency plan and emergency teams
Small rainwater channels	Workshops and training

#### **5.6.2.3.2 Revision and improvement**

The revision and improvement are implemented annually and whenever needed. Moreover, PDTRA is adopting the principle of build back better in its recovery phase after floods or any other disaster. Petra Authority works side by side with Petra governorate.

#### **5.6.2.3.3 Assessment**

PDTRA usually assesses the damages due to flooding by visual observation on the ground via a committee of engineers which reports to the top management to decide on the reconstruction of the damages occurred. The assessment involves housing, infrastructure, crops and agriculture, but also long terms damages to the eco-system, livelihoods, loss of income (from tourism for example) and other potential liabilities. PDTRA assesses the damages on regular bases using different available tools such as rapid assessment, field visits, interviews with affected people side walk.

#### **5.6.2.4 Early warning systems**

##### **5.6.2.4.1 Early warning systems**

- EWS is a tool used to receive forecast or real-time data from rain gauges to process these data and calculate the runoff that might leads to flood then issue a warning to target parties to take an action. An effective EWS needs to involve the local community at risk, facilitate awareness of risk, disseminate alerts and warning. A complete and effective EWS supports four main functions: risk analysis, monitoring and warning, dissemination and communication, and a response capability.
- EWS components are: Rain gauges, flowmeters, warning system, communication systems to send and receive data, computer and software to analyse data, rainfall-runoff model.
- EWS should be directed to local government, local communities, and economic and tourist sectors. Risk and alerts then should be disseminated to local communities and these sectors. Whereas some argued that EWS should be directed to local governmental institutions that concern about flash flood.
- Early warning systems related to floods have never been installed in the Petra region, but in the region, there is a system implemented in the Sinai Peninsula (Egypt). However, concerned authorities in the region deal with each rain storm according to its intensity at the time. Also,

these authorities depend on the forecasts of the Meteorological Department and eyewitnesses' data in the region. Local flood warning systems (LFWS) which are based on rainfall and river gauges, and flash flood guidance systems which are a combination of rain gauges, remote sensing data, and hydrologic models and rainfall forecast.

#### **5.6.2.4.2 EWS effectiveness**

EWS is an effective system if:

- EWS is an effective system if it has: (1) Reliable forecast or measurements (2) clear threshold for warning and alert (3) excellent system of communication (4) preparedness and drills.
- EWS would be an effective system and helps mitigating floods impacts when the four key elements are available: (1) Risk knowledge, i.e. risk assessment, vulnerability and exposure; (2) Technical monitoring and warning service; (3) Communication and dissemination of warnings; and (4) Community response capability.
- It gives enough lead time to enable responders to act as per plans set based on participatory approach and implement an evacuation if needed
- If it follows and applies the main component the EWS, trains others how to respond and communicate well with it, and what they should do when it is activated.

### **Part 4: Validation and Verification**

#### **5.7 Expert interview for validation**

Researcher conducted an interview to validate and refine the research findings. It is conducted using semi-structured interview method aiming to investigate whether the findings from qualitative analysis successfully captured the real phenomena of the investigated topic. The interview's questions are designed within three main themes: flood events and impacts, preparedness and mitigation, and early warning systems. The themes were based on the findings of the semi-structured interview (research objectives). Interview for validation guidelines are shown in Appendix (F).

Furthermore, the interviews were conducted with four experts on disaster risk reduction. The selection criteria for the interviewees was based on their experience. The interviewees had to have at least two experiences (flood risk reduction and flash floods events occurred) in case study location and to have come different job functions. Four interviewees were classified as satisfactory, because

after conducting the interviews all of them expressed their agreement with the research findings (see section 5.6). Coding and institution of interviewees are presented in Table 5.16.

Table 5.16: Interviewees data for validation

No.	Interviewee	Code	Institution
1	Interviewee 1	VAL1	NGO
2	Interviewee 2	VAL2	Academic sector
3	Interviewee 3	VAL3	NGO
4	Interviewee 4	VAL4	Government

### 5.7.1 Flood events and impacts

The key findings on the flood events and impacts are: floods events occurred in the area, flood-prone areas, and the impacts of floods at local communities and local authorities. Respondents were asked about their views about the flash floods events in the study area. They were asked “do you think that Petra Region has encountered to these flood events (mentioned in the question) between 1963-2015?” They were asked about flood-prone areas, “what do you think about these areas?” They were also asked about the impacts of floods and the casualties left after these floods.

#### 5.7.1.1 Flood events

All respondents agreed with the findings of the flash flood events, while some added some missing events. For example, VAL1 expressed his opinion as:

*“I totally agree with these figures that Petra Region actually encountered all of these flood events, but I found that the period between 1963 and 1994 has not been included in these inventories. Petra Region has encountered four floods during this period. These floods events occurred in 1968, 1970, 1974 and 1991”* said VAL1

*“The major flood events that had significant impacts on the Petra region can be attributed to the named years above. I personally dealt directly with those took place in 2010, 2011, 2012 and 2013 as the head of the winter emergency committee at that period in PDTRA”* said VAL2

*“Yes, Petra has encountered these flash flood events. I could add some other flash flood events occurred in Petra in most recent years such as 2005 and 2009. Moreover, another two flash flood events occurred in 2010”* said VAL3

*“I agree with these findings. Petra Region actually encountered to all of these flood events, but I could say that there is missing data still. Some flash floods also occurred within 1968 and 1991 which are not included in this inventory. Four floods during this period in Petra Region; 1968, 1970, 1974 and 1991”* said VAL4

Regarding the flood prone areas, the respondents think that the flood-prone areas are important to identify. According to VAL1, the identification of these areas leads the local authorities to adopt better prevention and mitigation measures to reduce flash flood risks:

*“Flood-prone areas are very important to identify. This leads the local authorities to adopt prevention and mitigation measures to reduce floods risks. Valleys and water streams are a real source of floods, especially, when water exceeds their limits. Thereafter, valleys and water streams’ boundaries are then prone to floods. Low areas and building close to valleys and water streams are definitely prone to floods and no less than valleys and water streams boundaries”* said VAL1

VAL2 added more flood-prone areas:

*“In addition to that the following areas and sites can be added: narrow streets in the neighborhoods, areas close to open sewerage nets, areas close to the open subsurface rainwater draining tunnels, areas under constructions (cut and filling processes), blocked areas with building residuals”* said VAL2

VAL3 added that the entrance of Petra and culverts are also flood-prone areas:

*“These areas are the most prone areas to flash floods in addition to the main entrance to Petra Archaeological Park and rainwater drainage culverts boundaries”*

VAL4 emphasised on the identification of the flood-prone areas and its importance which helps the local authorities to adopt the prevention and mitigation measures:

*“The identification of areas prone to flooding are an important and necessary issue, which helps local authorities to adopt prevention and mitigation measures to reduce flood risk. The main valleys in the Petra Region in addition to the water streams; that often feed valleys, are a real source of flooding, especially, when the water level exceeds the limits of the valley or water stream. Therefore, the valleys, water streams and their surrounding areas are of the most flood prone areas. Not to mention the low-lying areas and buildings built near valleys and streams that are certainly prone to flooding and not less likely than valleys and streams of water boundaries”*

#### **5.7.1.2 Flood impacts**

The findings from interviews indicate that flash floods left impacts at the tourism, economic, and social sectors, besides the effects at the infrastructure in study area such as: roads, retaining walls, sewage system, water and electricity networks, rainwater drainage systems, and irrigation canals, besides the impacts at the local community properties such as houses, vehicles, furniture, and electrical appliances.

VAL1, and VAL4 said that these impacts are comprehensive and covering, and they find some advantages for flash flood events; local authorities need to build back better.

*"I would consider these findings comprehensive and covering the flash flood impacts. I find these events sometimes useful in some ways. When flash flood occurs and leaves damages especially in infrastructure, local government then needs to rehabilitate and reconstruct the damages parts, local government then build back better to avoid any future damages"* said VAL1

*"I find these results realistic and summarising Petra Region's flash flood impacts. I find these events sometimes useful in some ways, because when authorities rehabilitate or reconstruct after damages caused by flash floods, they rehabilitate and reconstruct better than before"* said VAL4

VAL2 added that:

*"Area of Wadi Musa city can be considered as an end point where a huge catchment area of tens of square kilometers drain and collect their flood water before it gets re-directed via Wadi Al-Mudhlim to the PAP and then Wadi Araba areas, and for that and having the sophisticated topography of the city and its fragile geology, I agree with the findings above"*

VAL3 highlighted the psychological impacts:

*"I could confirm the effects and impacts that left by flash floods. I would add the psychological impacts at the local communities after the death of someone, or lost their properties"*

Regarding casualties, all respondents agreed with number of casualties mentioned which stated that flash flood in 1963 left 20-29 deaths, flash flood in 1996 left one deaths, and flash flood in 2001 left three deaths. They also stated that there were no casualties after 2001 but damages increased.

For example, VAL1 stated:

*"Yes, casualties; due floods, are: 20-28 deaths in 1963, one death in 1996, and three deaths in 2001. The good thing in this concern, no deaths occurred since 2001, but damages unfortunately increased"*

VAL2 argued that:

*"The number of deaths in 1963 should be determined and not be given as a category especially it is not so far event, and the event is registered in several authorities"*

VAL3 agreed with number of casualties differs from a narrator to another"

*"Casualties of the flash flooding in 1963 differed from a narrator to another, ranging between 18 and 28, but a lot of eyewitnesses confirmed the figure 28"*

VAL4 also confirmed the number of casualties:

*"Yes, I confirm these findings about casualties. In 1963, 20-27 deaths, one death in 1996, and three deaths in 2001 this from the one hand. From the other hand, no deaths occurred after 2001, whilst damages and economic losses increased"*

### 5.7.2 Preparedness and mitigation

Findings from interviews show that (1) procedure that might be followed in case of flash floods are quite known by local citizens, but could be enhanced by workshops, training and awareness campaigns (2) Most of citizens in Petra Region have undertaken independent measures to protect themselves and their properties from floods (3) Local authority needs to coordinated within its contingency plan with concerned parties to reduce flash floods risk (4) the mitigation and prevention measures that must be adopted by local authorities to reduce flash floods impacts.

#### 5.7.2.1 Preparedness

All respondents agreed that procedure that might be followed in case of floods is quite known by local citizens but could be enhanced by workshops, training, and awareness campaigns, whereas VAL1 stated that there is a lot that can be done in this concern:

*“Actions that must be taken when flash flood occurs are known by vulnerable citizens. I agree that workshops, training and awareness campaigns contributed in raising citizens’ knowledge, but I think there is a lot that could done in this concern”*

VAL2 stated that the knowledge and other methods are crucial need”

*“Let’s take this example: a flood is taking place while the children are in the schools, should the headmasters ask the parents to take their children back to homes, or should they wait until the flood ends, or should the children easily leave the school at the end of the lessons or before? Until now I can say that all schools in the city of Wadi Musa lack such knowledge in how to behave during flood events. For that the above listed methods are crucial need”*

VAL3 mentioned that:

*“Procedures, that might be followed when flash flood occur, are partly known to people at exposed areas, but they need more training through workshops and drills”*

VAL4 agreed with VAL4 and added the need to awareness and training:

*“Local citizens are aware to some extend of the procedure that might be followed when flash flood occurs is known, but awareness and training are required and likely to raise their knowledge and capacity to protect themselves from flash flood risks”*

For that independent measures that are undertaken by local citizens to protect themselves and their properties from flood impacts. VAL1, VAL2, and VAL3 confirm the validity of the findings.

VAL1 said the findings are true and added:

*“Citizen in Petra used to undertake independent measures such as sand barriers, establishment of the small channels around their houses, convert torrents pathways, source of illumination,*

*retaining walls, establishment of terraces, and construct their homes away from floodplains or valleys”*

VAL2 found these measures insufficient:

*“The independent measures they undertook are absolutely insufficient, and they must work in accordance with PDTRA’s Building Permits Directorate’s guidance and building regulations”*

VAL3 added:

*“The independent measures undertaken by local communities are simple but could not be considered enough, they must be trained how to evacuate or shelter and provided with the proactive measures to undertake before any flash flood event”*

VAL4 agreed with results but argued that citizen may lack sometimes to effective and practical measures:

*“Yes, I agree with that. Most of Petra citizens keen to undertake reasonable independent measures to protect themselves, their families, and their properties. They undertook any of independent measures relating to their experience, which may sometimes lack to effective and practical measures”*

For the coordination within contingency plan, findings show that PDTRA should coordinate within its contingency plan with concerned parties to reduce flood risks by: (1) Sharing data and information (2) Organizing joint awareness campaigns (3) Undertaking exercises and drills (4) Developing an early warning system (5) Reviewing and updating emergency plan (6) Lessons learned (7) Evacuation plans (8) Providing potential assistance. Respondents were asked about these aspects of coordination and their contribution to reduce flood risks.

VAL1 argued that:

*“The PDTRA contingency plan requires more coordination with local authorities such as police, civil defence, local governorate, and any other parties that may have a role in disaster time. Sharing data and information, awareness campaigns, drills and exercises, EWS, reviewing and updating, lessons learned, evacuation plans, and providing potential assistance, are good aspects to be considered to maintain coordination with all concerned parties”*

VAL2, VAL3, and VAL4 agreed that aspects of coordination contribute to reduce flood risks:

*“Most important thing is the integrated and well-prepared infrastructure to bear and drain flood water as fast as possible. The mentioned aspects then can reduce the risk of flood as anywhere in the world if professionally implemented”* said VAL2.

*“Yes, these aspects are good, but there must be a general contingency plan in the Petra Region that clarifies the roles of local concerned authorities in flash flood event time”* said VAL3.



*“Definitely. These aspects of coordination, if found or included in PDTRA contingency plan, will contribute positively in reducing flash flood risks. However, PDTRA need more coordination with local concerned authorities which their role revolves around the flood risk reduction” said VAL4.*

#### **5.7.2.2 Mitigation**

Findings from interviews show that Mitigation and prevention measures (structural and non-structural) must be adopted by Local government to reduce flash floods impacts such as:

- Levees, storage ponds, pumping stations, water canals
- Flood diversion and terracing
- Afforestation
- Water harvesting in small dams, pools, valleys
- Secure valleys’ borders and construct obstacles
- Developing infrastructure
- Restore valleys to their natural courses
- Invest in flood defences
- Early warning systems
- Training, awareness, drills and exercises
- Contingency plan
- Land use planning and sensitive risk land use planning
- Risk dissemination
- Monitoring flood risks

The experts in validation interviews were asked about these measures and if they agree with these measures. All respondents agree with these measures:

*“Yes, I agree with these prevention and mitigation measures to reduce flash flood risks” said VAL1*

*“I feel fine with these measures and the findings” said VAL2*

*“These measures sound very good and comprehensive which, if implemented, will prevent the people at risk and mitigate the flash flood risks that may occur in the area” said VAL3*

*“Yes, I agree with such measures to reduce flash flood risks. However, the non-structural measures are more important than the structural ones” said VAL4*

#### **5.7.3 Early warning systems**

The final theme in this interview, is the early warning systems. It is about EWS being effective and responsive. The respondents were requested to validate and confirm the requirements for the

effectiveness and responsiveness of the EWS. The requirements for effective EWS are: (1) reliable forecast or measurements (2) clear threshold for warning and alert (3) excellent system of communication (4) preparedness and drills.

The EWS is a responsive system when: (1) it gives enough lead time to enable responders to act as per plans set based on participatory approach and implement an evacuation if needed (2) it follows and applies the main component the EWS (3) trains others to respond and communicate well with it, and what they should do when it is activated.

#### **5.7.3.1 Effective EWS**

Respondents were asked to confirm and validate the findings from data analysis about the requirements of effective EWS. VAL1 said that:

*“EWS would be active if it has (1) reliable forecast or measurement (2) clear threshold for warning and alert (3) excellent system of communication (4) preparedness and drills. I would add also it should (1) involve the communities at risk (2) facilitate public education and awareness of risks (3) effectively disseminate alerts and warnings (4) ensure there is constant state of preparedness”*

VAL2 emphasised on the requirements of effective EWS and stated that:

*“From a technical point of view, these are essential requirements of the EWS to work with high accuracy, in addition to that the system can be adjusted with time by learning from the lessons of each flood event”*

VAL3 emphasised the excellent system of communication, and the community preparedness and drills and stated that:

*“I agree with these requirements that make EWS an active system. I would emphasise at excellent system of communication, and the community preparedness and drills that, if available, will increase the effectiveness of the system”*

VAL4 found these requirements are essential for EWS to be effective:

*“These requirements are essential for EWS to be effective. Forecast and measurements should be reliable, threshold has to be clear to issue the warning the right time, the warning should be effectively communicated with people at risk, and people at risk will respond if they are constant state of preparedness”*

#### **5.7.3.2 Responsive EWS**

Respondents were asked to confirm and validate the findings from data analysis about the requirement of responsive EWS. VAL1 agreed with these findings and added:

*"In general, a complete, responsive and effective early warning system supports four main functions: (1) risk analysis (2) monitoring and warning (3) dissemination and communication (4) a response capability"*

VAL2 emphasised on the purpose of the system by:

*"Main purpose of the system is to issue alarm in the suitable time before the flood, and the most important is the reliability of the cautions, then we can say it is an effective system"*

VAL3 argued that:

*"EWS would be an active and responsive system when these factors are available. However, the risk analysis, monitoring and warning, disseminating and communicating risk with people at risk, and the ability of the local authorities and communities to respond, are main factors to make EWS a responsive and active system"*

VAL4 agreed with VAL1 that:

*"A complete and effective EWS basically supports four main roles: (1) risk analysis (2) monitoring and warning (3) dissemination and communication (4) a response capability"*

## **5.8 Summary**

This chapter contains four main parts; the introduction to case study, the qualitative data analysis, the results and findings, and the validation of the data analysis findings. The first part describes the geography, demography, hazard profile, and flash floods impacts in Jordan and in the case study area. 98.8% of Jordan population are potentially exposed to seismic, floods, landslides and climatic hazards, while the total deaths exceeded 650 and total affected people exceeded 355 thousand. The flash floods have effected Petra Region and have left many losses and damages; i.e. in 2013 the losses were \$5-7 millions.

Part two consists of two sections, in the first section (5.4), three semi-structured interviews were conducted and analysed. The result led the researcher to conduct twenty semi-structured interviews in two groups; users and experts. The data was analysed using content analysis. Some responders highlighted the flash floods events and their impacts, local community preparedness, and local authorities were revealed. While, in the section 5.5, documents that have been reached through the Petra region tourism development authority (PDTRA) were reviewed. The documents revealed the full inventory of flash floods events that threatened Petra Region for more than 50 years. Documents also identified the flood and flash floods prone areas.

The third part discussed the results of research drawn from semi-structured interviews (section 5.6). The interviews were a very good source for accomplishing the second objective; *review the incident reports of previous flood events in the Petra area*, as there are insufficient studies of these events.

The results also showed areas prone to flooding, the preparedness of local authorities and communities to deal with floods and the measures adopted to mitigate their effects and risks; such as risk knowledge, awareness and training. The results also showed the roles of the local authorities in dealing with the floods and their commitment on the one hand. On the other hand, it clarified mechanisms of coordination and cooperation among the authorities and relevant governmental institutions, and the local community and its organizations in dealing with the impacts of floods.

Part four presented the validation and verification for the findings of the research through the semi-structured interviews. The results were validated and verified within three aspects; flood events and impacts, preparedness and mitigation, and early warning systems. The validation and verification were implemented by conducting a semi-structured interview with four experts. Most of the interviewees emphasised on the results captured from users and experts' interviews. Having analysed, discussed, and validate the results, the next chapter will present that final framework for this research.

## **Chapter 6      Final Framework**

### **6.1 Introduction**

Chapter 5 presents the analysis of qualitative data of this study. This chapter presents the empirical findings of the research and triangulates them with the literature. The structure of this chapter is as follows; first, it presents findings that focus on the context of the early warning system guidance for flash floods (FFEWSG). The definition, advantages and limitation of the guidance are presented. Then, it presents the findings from the implementation of FFEWSG in the study area. Next, it presents the refinement of the conceptual framework through data findings. Finally, the validation and verification of the final framework with Petra Region mitigation and prevention system.

### **6.2 Flash flood early warning system guidance (FFEWSG)**

#### **6.2.1 Definition**

Flash flood early warning system guidance (FFEWS) is a model to study the processes of existing flash flood management, modify where the existing processes are required, develop the how these processes should be performed, and establish guidelines and procedure which, if followed, would lead to improve the performance of these processes. It will be a basis for local authorities to establish their own early warning system targeting local government, local communities, and Petra visitors (Tourists), and investigate the potentiality, scientific, and practical benefits of the system as a tool to mitigate the floods risk in the study area.

Flash Flood Early Warning System (FFEWS) provides a rational basis for flood management decision-making at a national scale and locally. Petra region has a notorious history of extreme floods that had caused serve damage to the installations located in its floodway and considerable distances downstream.

In the Hyogo Framework for Action (2005-2015), it is stated that saving lives depends on functioning early warning systems and therefore on local early warning centres that have the capacity to respond immediately to nationally broadcast early warnings or pick up on local warning messages. This requires dedicated financial and human resources to ensure continuous functioning of the centre.

This guidance will connect the (EWS) with Petra development and Tourism Authority (PDTRA), public security, civil defence, local governor. The guidance will develop the process of issuing alarms for sufficient time to enhance local government and communities' preparedness, therefore, people,

tourists, and any other parties, are warned of an emergency over Radio, TV, the sound of the public warning signal (outdoor sirens) which must be distributed over the whole area to cover all people in the study area. Local government (Petra Authority) will own this guidance. The beneficiary parties of this guidance, in addition to local authority, police, security, civil defence, will be local communities, local agencies and non-governmental organisations, tourists and visitors, community-based organisation and governmental organisations.

### **6.2.2 Factors that Determine the Benefits of EWS's**

EWS's provides information about the potential future flash floods that may threaten injury or loss of life and damage to properties. To determine the benefits of EWS, Teisberg and Weiher (2009) mentioned six factors that determine the gross benefits of EWS's. Frequency and severity related to nature of the natural disaster, lead-time, accuracy, response costs, and loss reduction, are jointly determine the most appropriate response when disaster warning issued.

### **6.2.3 Advantages**

Early warning gives people time to flee from flash flood, tornado or tsunami; enable local authorities to evacuate or shelter large number of people in advance of a tropical cyclone or hurricane; provide information on the occurrence of a public health hazard; and enable a faster response to problems of food and water insecurity.

There is no doubt that effective EWS's have substantially reduced deaths and injuries, economic losses from severe weather events.

In order for the benefits of an early warning system to be high, a natural hazard must simultaneously satisfy several criteria: it must be frequent, severe, predictable with reasonable lead-time and accuracy, and there must exist cost-effective responses to warnings of an impending occurrence. If any one of these criteria is not met, the potential benefits from a warning system may be small or even zero (Teisberg & Weiher, 2009).

## **6.3 Refinement of conceptual framework**

The objective of EWS's is to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment (ISDR, 2006b). Flood warning systems provide a well-established way to help to reduce risk to life, and to allow communities and the emergency services time to prepare for flooding and to protect possessions and property. They can help to reduce the effects of flooding by allowing people to be evacuated from areas at risk, and to move vehicles and

personal possessions to safety. With sufficient warning, temporary defences can also be installed to mitigate the effects of flooding. A flood warning system can include rainfall detection systems, flood forecasting models, flood warning and dissemination systems, and emergency response procedures (Sene, 2008). Best practice early warning systems also have strong inter-linkages and effective communication channels between all of the elements (ISDR, 2006b). Each link in this chain is important, and the modern emphasis is on a Total Flood Warning System (Emergency Management Australia 1999) or people-centred approach, in which communities provide inputs to the design of flood warning systems, and help with their continuing operation (Basher, 2006; ISDR, 2006b; Martini & De Roo, 2007; Parker, 2003).

Developing a framework that will enable responsive and effective EWS in Petra Region is very important in interpreting the research results into considerable contribution to EWS practice and theoretical context. The following aspects have informed the development of the final framework:

- Literature review: as mentioned earlier in section 3.5 that conceptual framework elements were drawn from some existing systems as shown in Table 3.1. These elements were added in the initial conceptual frame as presented in section 3.5 and Figure 3.1.
- Empirical findings from semi-structured interviews with users, experts and validation by selected group of experts: in section 5.4.4.4.1 and section 5.7.3, most of the interviewees mention the component of the early warning systems as:
  - Rain gauges to measure the amount of rainfall and intensity of precipitation.
  - Flow gauges to measure the height of water runoff levels in the valleys
  - Alert system (voice or message)
  - Communication control unit
  - Receiver and transmitter
  - Computer and Software to process the measured or predicted values through a special model (i.e. rainfall-runoff)
  - Reliable forecast or measurements
  - Clear threshold for warning and alert
  - Excellent system of communication
  - Preparedness and drills.

The literature review findings, initial conceptual framework and finding from semi-structured interviews (experts and validation for findings) have helped to develop the final framework. The framework was developed through two distinct phases: (1) flash flood monitoring and warning

phase, and (2) response phase. Each of these two phase eventually consists of number of sub-phases, which are linked through dissemination and warnings (see Figure 6.1). The next sections present more details about these elements.

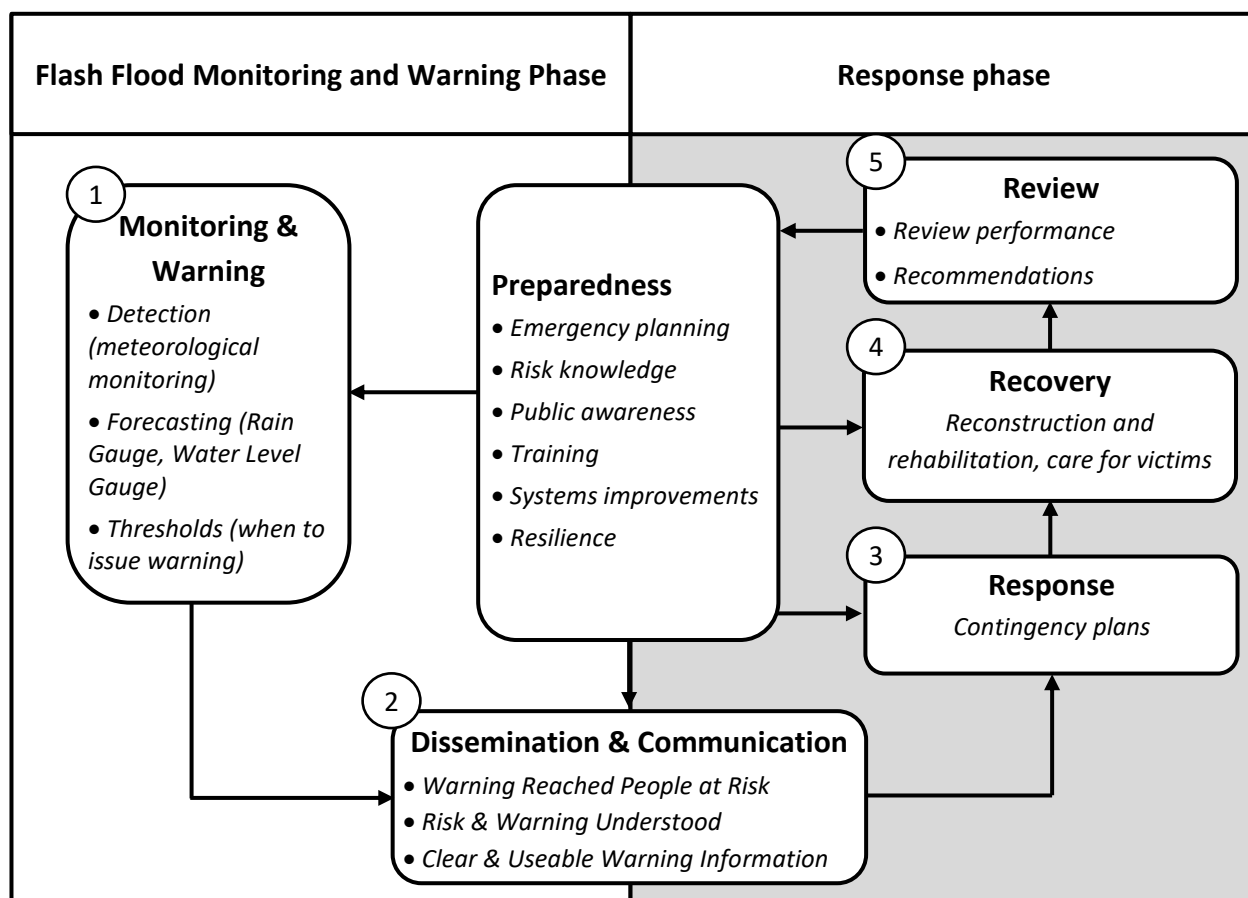


Figure 6.1: Final Framework for Flash Flood EWS Guidance

### 6.3.1 Flood monitoring and warning Phase

The flood warning phase; as mentioned in section 3.5.1, needs continuous monitoring of the weather conditions to let detection and assessment of the threatening events to take place before they hit a community. Forecasts may also be made to help decision-maker model how an event is likely to develop, how significant it will be upon arrival, and what sections of the community are likely to be at risk (Linham & Nicholls, 2010). The next sections present this phase in more details.

#### 6.3.1.1 Monitoring and Warning

Monitoring and warning (1) consists of the sub-phases; detection, forecasting, and thresholds. These sub-phases are discussed in the following sections.



#### **6.3.1.1.1 Detection**

As discussed in section 3.5.1.1, most flood warning systems use near real time measurements of meteorological conditions to guide operational decision making, which include information on rainfall, water level, wind speed, and other parameters. Also, meteorological information for flood warning and forecasting applications are: (i) measurements at selected locations using rain gauges, water level gauges, automatic weather stations (ii) Remote Sensing based on satellite observations, weather radar. Therefore, the detection proposed in this framework is:

- Measurement of rainfall (precipitation amount) using tipping bucket rain gauges at selected locations in the flood-prone areas in the Petra Region as stated by user and expert interviewees in sections 5.4.3.1.2 and 5.4.4.1.2. These rain gauges would send the rainfall reading to control room when depth reaches sufficient amount. Typical bucket sizes are equivalent to rainfall depths in the range 0.1–2.0 mm, with the choice of tip size often based on the maximum rainfall intensities anticipated at the site. Each tip is recorded, together with the time of the tip, and can be reported by telemetry directly, or accumulated to fixed time intervals before transmission.
- Rainfall (precipitation amount) prediction using remote sensing based on weather radar.
- Measurement of water level using water level gauges in the main Wadi's that are passing through the residential, tourism, economic areas in Petra Region that are stated by expert interviewees in section 5.4.4.1.2 that these Wadi's constitute a major factor in flood occurrence in the region. These reading would be sent to control room at given level as well.

Detecting meteorological information will indicate if the flooding threshold reached the level at which flooding occurs.

#### **6.3.1.1.2 Forecasting**

As discussed earlier in section 3.5.1.2, forecasting is the application of science and technology to predict the state of the atmosphere for a given location and at a given time. It covers a wide range of numerical, empirical, observational and other techniques, and in operational forecasting the final decisions on the forecasts to issue are often taken based on a combination of these approaches. For flooding forecasting, two approaches are of interest: Numerical Weather Prediction models and Nowcasting systems. Through the semi-structured interviews, it is found that local community claim that weather forecasting information is not enough accurate, inadequate, and limited, therefore, this research framework will adopt nowcasting system approach, which provides short term forecasts; i.e. several hours, based on a combination of weather radar.

Forecasting the state of the atmosphere will indicate if the flooding threshold reached the level at which flooding occurs.

#### **6.3.1.1.3 Thresholds (triggers)**

As presented in section 3.5.1.3, thresholds are the values at which flooding occurs. Threshold values may be set based upon experience or analysis of historical data, or using conceptual, data based or process based modelling studies. The EWS sends alerts according to the user pre-defined thresholds. The thresholds at which the warning will be issued in Petra Region would be defined based historical data. For the alarm trigger, it is proposed that:

- The rainfall rate to trigger alarm: 10 mm in one hour, or 25 mm in 3 hours, or 40 mm in 6 hours
- Water level limit to trigger alarm: once it reaches detectable limits of the trigger.

Reaching flooding threshold, the warning of an approaching flash flooding is issued and disseminated to concern parties.

#### **6.3.1.2 Dissemination and Communication**

The dissemination of warning (2); that links flood warning stage and response stage, presented in section 3.5.2, needs to be issued to the public, emergency services, local authorities and others with an interest in when and where flooding is likely to occur, or who are involved in the emergency response. Moreover, dissemination techniques can broadly be separated into indirect methods, community based methods, and direct methods. In this framework, the dissemination techniques will be: (i) *direct methods* which targets representatives of communities, local authorities, emergency services and key responders using telephones, cell phones, fax, two-way radio, and email (ii) *Community based methods* which targets local communities using sirens, flags, and billboards.

By using these two techniques, the warning will reach: (i) people at-risk to give them advice on what to do in the event of a flash flood, as well as providing further information to limit losses by taking actions to prevent themselves and their assists. Advice may also include areas to be evacuated, evacuation routes and the location of refuges for evacuees (ii) local authorities to initiate the response plan, allowing more effective use of staff and other resources, and avoiding the unnecessary of evacuation of properties.

In communicate risk information and early warnings, it must ensure that:

- Warnings reach all those at risk, such as local communities in low-lying areas, the people within the business and tourist areas, workers in infrastructure projects in low-lying areas, schools and universities students, as well as a focus on children, women and elderly people who are at home

- The risks and warnings are understood by all of those at risk and any targeted groups as well by conducting training programmes and having written brochures, banners, or short messages in mobiles or billboards.
- The warning information are clear and useable. The warning information should be written in a simple language that clarifies the action and could be used by all of those at-risk.

### **6.3.2 Response phase**

After the disseminating warning to the public, emergency services, local authorities and others with an interest in when and where flooding is likely to occur, second phase of the flash flood EWS guidance is initiated; the response phase (see section 3.5.3). At-risk people need to take action in cooperation with local authorities to minimise their exposure to the hazard and to reduce the social consequences of flash flooding. Response consists of preparedness, response, recovery, and review. These sub-stages are discussed in the next sections.

#### **6.3.2.1 Preparedness**

Preparedness is defined in disaster risk management section 2.4 by Sena and Michael (2006, p. 114) as a state of readiness to respond to a disaster. As presented in section 3.5.3.1, the effectiveness of response to a flood event can be improved if an emergency plan has already been prepared, so that all participants understand their roles and responsibilities, including the overall chain of command. The most important issues in preparedness are: flood emergency planning, risk knowledge and public awareness.

***Flood emergency planning:*** Flood Emergency Plans are the action to be taken during and after flash flood event that cover operational procedures, emergency response assets, contact details for key staff, health and safety issues, procedures for liaison with the media and the public, and information on safe access and evacuation routes and shelters. In this proposed framework, actions need to be taken by local authorities in the run up and during flash flood events as suggested by Sene (2008), and also interviewees in section 5.4.3.4 stated some of these actions:

- Providing search, rescue, and evacuation services for population affected.
- Scheduling closure of schools and transportation of students from flood-prone areas.
- Curtailing electric service to prevent electric shocks.
- Establishing traffic controls to facilitate evacuation and prevent inadvertent travel into hazardous areas
- Dispersing fire and rescue services for continued protection

- Establishing emergency medical services and shelters
- Closing levee openings
- Moving public and private vehicles and equipment from areas subject to flooding
- Relocating or stacking contents of private structures
- Initiating flood-fighting efforts (e.g. sandbagging etc.)
- Establishing security to prevent looting

The roles and responsibilities of inter-agency coordination is often an important consideration in developing flood emergency plans, however, interviewees stated in section 5.4.3.4.1 that there is a coordination to some extent between governmental institution during emergency time. Moreover, at community/region level, plans might include:

- Identifying and maintaining of safe havens, safe areas and temporary shelters
- Putting up signs on routes or alternate routes leading to safe shelters
- Informing the public of the location of safe areas and the shortest routes leading to them
- Having all important contacts ready: district or provincial and national emergency lines; and having a focal point in the village
- Making arrangements for the damage and needs assessment team and health team
- Setting up community volunteer teams for a 24-hour flood watch
- Improving or keeping communication channels open to disseminate warnings

Distributing the information throughout the community

**Risk knowledge:** One key stage in developing a flood emergency plan is to assess the flood risk, and to tailor the response to the level of risk. Flood risk can be expressed in terms of the probability of flooding and the likely impacts; i.e. people or properties at risk, economic value. In this framework, the flash flood risk and impacts should be assessed in terms of flood plains, number of people at flood-prone areas that have been identified by interviewees in sections 5.4.3.1.2 and 5.4.4.1.2. PDTRA has conducted a study to assess flash flood risks (see section 5.5.3) and identified the flood impacts at people and properties, flood plains, and infrastructure.

**Public Awareness:** Communities are exposed and vulnerable to flash floods risks, it is important to communicate appropriate actions to public through awareness raising campaigns, before an emergency. These campaign will empower local communities to take action more quickly and help to mitigate the consequence of flooding to the greatest degree (Linham & Nicholls, 2010). It is

important that local community members themselves are aware of flash flood risks and vulnerabilities.

According to interviewees opinions in section 5.4.3.3.3, raising awareness about community-based disaster risk reduction; disaster prevention, mitigation and preparedness; among DRR stakeholders and vulnerable groups could be achieved by using various means such as awareness classes, door-to-door campaigns, and training. In the awareness and training programmes, many issues must be clarified for those of vulnerable groups such as: the evacuation plan, shelters, alternative roads, medical care centres. Moreover, section 5.4.4.2.3 pointed that raising awareness among local communities could be through the following issues: awareness campaigns, participatory processes, drills and exercises, community engagement, training and workshops, lectures, media and social media, neighbourhood disaster volunteers, participation in decision making, and consultation with all concerned stakeholders.

Another way to develop this flash flood risks and vulnerabilities in the community is through risk assessment and risk mapping exercises to help prioritize which hazards an early warning system will focus on and guide response preparedness activities, as well as disaster prevention. These assessment and mapping exercises could be based on the community's different categories of vulnerabilities (human, social, economic and environmental), as well as their previous experiences with natural hazards (Cowan et al., 2014). In this research framework, the public awareness is an important issue that contributes positively to early warning for flash floods in Petra Region.

#### **6.3.2.2 Response (Contingency plans)**

As mentioned earlier in section 3.5.3.2, flood warnings provide local authorities, the emergency services, the public and others with time to take actions to reduce the risk from flooding, and information on the likely extent and locations of flooding. The action that could be taken by local authorities; i.e. PDTRA, and emergency teams; i.e. civil defence, before flash flood starts including protection of private properties, evacuation of people from flood-prone areas, positioning required vehicles and assets in location, temporary flood defences. Moreover, local communities need to take actual action to prevent themselves and their properties from flash floods impacts. Referring to interviewees opinion in section 5.4.4.2.2 about PDTRA contingency plan (3) and the coordination with other concern parties, most of these opinions stated that PDTRA has an emergency plan, and has; to some extent, a coordination with other concerned parties. However, various actions can also be taken to reduce or even prevent flooding, including:

- Emergency works – reinforcement of weak spots in flood defences, and at locations where existing river or coastal works are underway (and patrols to inspect defences and other structures), clearance of drains and blocked watercourses
- Temporary defences – raising temporary or demountable barriers, placing sandbags along flood defences and river banks, and at individual properties
- Flow control operations – diversion of river flows, closing (or opening) gates, emergency draw-down of reservoirs etc.

#### 6.3.2.3 Recovery

Recovery sub-phase (4) will take place aftermath of flash flood event. The following actions are required to be taken actions:

- Make property safe
- Remove debris and decontaminate sites
- Return people to their homes and reuniting families
- Providing shelters, food, water, medical care
- Emergency funding arrangements

As mention in section 3.5.3.3, PDTRA flood emergency plan should state which organisation(s) will assume responsibility for repairs, debris removal, reuniting families, emergency funding arrangements, and providing shelter, food, water, medical care, counselling, support to businesses, and restoration of services if interrupted (power, water, communications etc.)

#### 6.3.2.4 Review system

According to interviewees opinion in section 5.4.4.3.2, review (5) is usually conducted following any major flood events in PDTRA, which is a part of it continuous improvement in Petra Region. Moreover, PDTRA usually assesses the damages due to flooding by visual observation on the ground via a committee of engineers which reports to the top management (Commissioner for infrastructure) to decide on the reconstruction of the damages occurred. However, when a flash flood warning system is installed in the region, it requires a periodic review to address the faults and weaknesses, and enhance the strengths in the system. Then review process must include the performance monitoring, recommendation for improvements.

Sene (2008) stated that **performance monitoring** usually consists of a process of reviews, recommendations, implementation of findings, and continuous assessment to check that recommendations are being acted upon, improvements are being made. Also, flood warning

services increasingly need to demonstrate the benefits that they bring, and that improvements are being achieved over time. Routine review may be performed against targets, and areas that may be changed (key staff, equipment, procedure), through workshops and research studies. Therefore, PDTRA should conduct periodic tests and exercises that can help identify problems, and keep staff trained in use of systems.

If PDTRA adopts this guidance, it should refer back to previous studies, and a record should be maintained of findings over the years, including changes that influence flood response and flood warnings (e.g. to flood defences, instrumentation, control structures etc.).

Post event reviews, and regular performance monitoring, can lead to a range of ***recommendations for improvement***, which might include (Sene, 2008):

- Detection – improvements to meteorological (e.g. site locations, types of instrument, accuracy), and meteorological forecasts
- Thresholds – revision of threshold levels to reduce false alarm rates, improve success rates, provide more lead time, provide backup in case of failure etc.
- Dissemination – improvements to systems and procedures to increase the proportion of people at risk receiving warnings, change the wording of messages, update flood risk assessments, raise public awareness etc.
- Forecasting – improvements to models and systems, such as recalibration of models, use of more sophisticated models, use of data assimilation, use of ensemble techniques
- Preparedness – revisions to flood emergency plans, more frequent and detailed emergency response exercises etc.
- Response – improvements to inter-agency coordination, information and communication systems, liaison with the media etc.

More requirements may also be identified at an organisational or national level; for example, the need to extend the flood warning service to new locations, to introduce greater consistency in procedures, and to provide warnings for additional types of flooding, such as urban flooding, or for fast response catchments. However, international reviews and comparisons may also highlight potential changes (Parker *et al.*, 2007).

An effective flood warning service requires cooperation between different agencies, such as the government, relief agencies and local communities. As such, this approach not only provides

technical challenges but also, organisational ones (Linham & Nicholls, 2010). Sene (2008) stated that effective warning service requires some of the essential components as shown in Table 2.7.

It is important to note that a flood warning system is not a standalone response to minimisation of the impacts of coastal flooding. An early warning system should be coupled with emergency planning measures, such as the provision of evacuation routes and flood shelters, and should also contain an awareness raising element. These systems are only useful when everybody knows what the system of warning means, what the stages of warning are and what to do when the warnings are given (Tompkins *et al.*, 2005).

Early warning system needs to be supported by information about the actual and potential risks that a flash flood poses, as well as the measures people can take to prepare for and mitigate its adverse impacts. Early warning information needs to be communicated in people friendly manner in such a way that facilitates decision-making and timely action of response organizations and vulnerable groups. Specific information about flash flood that should be included to facilitate decision making are: action that should be taken to reduce loss of life, injury, and property damage, flood-prone areas, evacuation roads, safe areas, and temporary shelters.

#### **6.4 Summary**

In this chapter, the final framework for FFEWSG was presented after modification of the conceptual framework presented in Chapter 3, which consists of two phases; flash flood monitoring and warning phase, and response phase.

In section 6.2, flash flood early warning system guidance (FFEWSG) was defined, its factors that determine the of EWS and advantages were determined. Section 6.3 presents the refinement of the conceptual framework and its stages.

Next chapter seeks to further synthesise the findings and re-visit the objectives of the study to ensure that the objectives of the study are achieved. It also presents the contribution of this research to theory and practice, the limitations and future research that can be identified from this research.



## **Chapter 7      Conclusion**

### **7.1 Introduction**

This chapter summarises all aspects of this research on the objectives shown in section 1.3 of this research. The chapter consists of three sections: section 9.2 is a discussion about the research objectives which shows to what extent these objectives were accomplished and how they were accomplished. The findings related to each objective are presented in section 7.3. Section 9.4 presents the contribution to knowledge and practice. Section 9.5 presents the recommended future research. Section 9.6 shows the final note for this research.

### **7.2 Summary of research aim and objectives**

The main findings to date showed that Petra Region has many strengths; good institutional and social infrastructure, that could be used to establish an early warning systems for flash flood. Strategies for preventive flood risk management; including structural and non-structural measures, are available, regulation measures for land use and the planning of settlements are also available but there is no enforcement, economic measures for regulation are not available at the moment, and promotion and communication are very weak.

The research has explored and investigated the concept of EWS, in order to develop Flash Flood Early Warning System Guidance (FFEWSG) in the Region of Petra aiming to enhance resilience. In achieving this aim, the research specifically investigated the early warning systems related to flash floods and these systems could contribute to reducing flash floods impacts. Accordingly, the following objectives were developed and examined through literature review and interviews:

- To explore the key determinant of flash floods in developed and developing countries.
- To review the specific factors that contribute to flash flood events in Petra Region and their impacts at the study area.
- To critically review the best practices of early warning systems related to flooding.
- To identify elements for an effective early warning system guidance for flash flood.
- To develop a guidance to a responsive early warning system for flash flood in the study area.

## 7.3 Summary of key findings

### 7.3.1 Objective one

The first objective of the study is **“to explore the key determinant of flash floods in developed and developing countries”**. The study sought to trace back the flash floods events and their impacts; economic damages, life losses occurred at global level; developed and developing countries (see section 2.3.2).

Floods and flash floods are known as frequent and most devastating events worldwide due to different reasons and several of these reasons are correlated as a result from the confluence of both meteorological and hydrological factors exacerbated by human actions. They inflict many losses to both developed and developing countries in terms of lost lives, destroyed properties, as well as health hazards brought about by the floods. In period between 2000 and 2016, countries around the globe have encountered 2750 flood events, 92,191 deaths, 1.46 billion people have been affected, and a total damage of US\$ 458 billion in damages (see Table 2.3). Developing countries are the most affected by flash floods. Asian region is the most affected by flash floods and countries like India, China, Pakistan, Indonesia, Haiti, Brazil, Thailand, Afghanistan, Vietnam, and Philippines are extremely vulnerable (see Table 2.4). It indicates that most floods and flash flood disasters' victims are poor people of developing countries, who suffer the most and are the first casualties of such incidents because poor communities often live in the most hazardous and unhealthy environments in urban areas. They build their homes and grow their food on river floodplains. Some others construct their shelters on steep, unstable hillsides, or along the foreshore on former mangrove swamps or tidal flats. Therefore, people affected by these poor conditions may also find their problems being compounded by the consequences of climate change.

Floods and flash floods cause immense damage in developing countries and huge proportion of such destruction is associated with lack of knowledge, resources and coping mechanisms. Therefore, efficient management of floods is essential. This includes accurate projection of floods and flash floods such as EWS, proper planning of settlements and environmental conservation, which improves on the predictability of torrential rains and storms that cause extensive flooding.

There are big differences between developed and developing countries in terms of flash floods and their impacts. These differences are related to absence of a comprehensive flood risk mitigation plans in the developing countries. These plans are usually composed of a series of measures

implemented in the catchment scale that ensure a limitation of flood hazard and exposure such as: flood hazard mapping, early warning systems, terracing, etc. (see Table 5.11).

### 7.3.2 Objective two

The second objective of the study was **“to review the specific factors that contribute to flash flood events in Petra Region and their impacts at the study area”**. The study sought to investigate the incident reports of the previous flash floods and their effects at Petra. The literature review conducted revealed some of flash floods and their common impacts on the study area.

Reviewing literature presented a revision of incident reports of previous flash floods events in Petra Region and how these flash floods affected the study area. whilst some studies looked at the flash floods and their impacts Jordan during recent years (see section 3.4), not many have investigated all the flash floods occurred in the Region as well as their impacts (see section 3.5). Accordingly, a semi-structured interview was conducted to explore the flash flood events and how they affected the study area during the past years (see sections 5.4 and 5.6).

The case study confirmed that the study area was exposed to many flash flood events during the last 50 years in which the study area had been affected by these floods on a number of aspects such as: losses in lives, damages in private and public properties, damages in infrastructure, and economic losses. The economic losses were related to damages in the infrastructure and the need to reconstruction, closure of the archaeological site which leads to losing entry tickets in the closure time, damages in tourism, economic and residential areas.

The findings confirmed that flash floods occurred after 2003 had not left deaths due to mitigation measures that had been adopted by local authorities and local communities on the one hand, on the other hand, damages were increased, due to urban expansion, which led to the changing the natural trends and tracks of the rainwater.

Analysis of impacts on the case study provided a comprehensive account of how different impacts trigger other risk, such as landslides and erosion occurred in the streets and retaining walls especially stone ones.

### 7.3.3 Objective three

The third objective of the study was **“to critically review the best practices of early warning systems related to flooding”**. The EWS's that are mainly adopted by some developed and developing countries to reduce flooding impacts (see section 2.5.3. These systems have contributed to reduce flash flood impacts such as casualties, damages, and economic losses, for example, EWS established

in Belgium, supported mobilization of emergency response and provision of public warning. The forecast results underpin a decision-support system, giving basin managers the information they need to make informed judgements for disseminating flood warnings and altering their management of the river controls. The Australian EWS contributed to raising low levels of community emergency preparedness in many Australian communities, designing effective flash flood warning systems, and understanding potential community response behaviours.

America has developed a Flash Flood Guidance System with Global Coverage (GFFGS) that can be used as a diagnostic tool, but no national flash flood rain gauge/stream flow network, whilst, in Central America, an EWS for flash floods implemented which so call Central America Flash Flood Guidance (CAFFG).

Some other EWS's have been established in developing countries such as Kenya, Egypt, and Colombia. The Kenyan flash flood early warning; which is being developed in Kenya, could significantly reduce the number of fatalities due to flash floods, improve the efficiency of disaster risk reduction efforts and play an important role in strengthening the resilience to climate change of developing countries in Africa.

The Egyptian flash flood manager (FlaFloM); that have been developed in 2008, was able to forecast the last two flash floods, on 24 October 2008 and 17–18 January 2010 with an underestimation for the 2008 event and an overestimation for the 2010 event.

The Aburrá Valley Natural Hazard Early Warning System (AVNHEWS) was designed; as an end-to-end EWS, to reduce the loss of life and suffering caused by floods, flash floods within the Aburrá Valley. AVNHEWS will also build national capacity in overall rainfall estimation and flash flood prediction throughout Colombia.

#### **7.3.4 Objective four**

The fourth objective of this research was **“to identify elements for an effective early warning system guidance for flash flood”**. This objective has been accomplished partially in chapter 3 and then refined at chapter 6. The empirical proposed elements for the early warning system guidance for flash flood are:

- The monitoring and warning; which consists of detecting rainfall by meteorological monitoring, forecasting, and thresholds to issue warning.
- The repose; which consists of response, recovery; reconstruction and care for victims, and review; performance and recommendations.

- Dissemination and communication; that links the elements of monitoring and warning, and response, emphasised that: Warning Reached People at Risk, Risk & Warning Understood, and Clear & Useable Warning Information.
- Preparedness that consists of many important issues such as; emergency planning, risk knowledge, public awareness, training, systems improvements, and resilience.

These elements will be considered as empirical evidence for the early warning system guidance for flash floods. They could be modified after reviewing the performance of the guidance and having recommendations for improvement as mentions in section 6.3.2.4

### 7.3.5 Objective five

The fifth objective of the study was **“to develop a guidance to a responsive early warning system for flash flood in the study area”**. The results from objective 1 and 2 have shown that many countries in world; developed or developing countries, have witnessed many flash floods. These flash floods have left losses in lives and damage in properties, which caused great loses in these countries’ economy. The results from objective 3 have shown that EWS’s are used in some countries around the world; such as Australia, Belgium, Egypt, which contributed positively in flood risk reduction in some countries, and have not been examined or under construction in some other countries. The results from objective 4 were essential to accomplish this objective.

Achieving objective 5 has been the core of this research from the beginning, while developing Flash Flood Early Warning System Guidance (FFEWSG) in the study area is very important to translate the research outcomes into significant contribution to EWS practices and theoretical context.

The guidance to a responsive EWS in study area that has been designed; (see Figure 6.1), consists of four phases; flood monitoring and warning, and response phase, in which, every phase leans at its previous stage. On the other hand, every phase has its own components and requirements that contribute to the achievement and success of that stage. The involvement of local communities in EWS showed an important issue that needs to be considered. Therefore, it is very important to raise the local communities’ risk knowledge, awareness, training, and benefit from their available experiences and knowledge.

## 7.4 Contribution to Knowledge and Practice

The study makes a noteworthy contribution to theory and practice in the subject domain of early warning system for flash floods. The next two sections illustrate this contribution.

#### **7.4.1 Contribution to theory**

This study merged literature from four main areas: flood, flash floods and their impacts at the developed and developing countries (see section 2.3), disaster risk management and flood risk management (see section 2.3.4), early warning systems (see section 2.5), and flash flood impacts at Jordan in general and Petra Region in particular (see section 2.3.4). By merging the concepts and theories on the subject areas, this study provided a better understanding for flash floods and their impacts at the Petra Region in particular. The following provides details of how this study has contributed to theory in these areas.

This research has contributed to theory by developing the theory of flash flood events and their impacts. The development of the flash flood events and their impacts theory was accomplished through reviewing the available literature about (i) flash floods in the study area (ii) early warning systems (iii) the best practices of early warning systems related to flash floods. This development led to build the initial guidance. Then collecting data through interviews to combine it with finding from literature review and initial guidance to build the theory (the final guidance with its elements).

This study has contributed to theory by establishing a simple definition of the flash flood early warning system guidance (FFEWSG) in the context of flash flood mitigation measures, and provided the factors that determine the benefits of the guidance (see section 2.5.4). In terms of specific contribution to knowledge, the research has provided the empirical evidence on the elements of the guidance within early warning systems for flash flood and how these elements can help to improve the management of flood risk (see section 6.3). This study will be an added-value to the theory of EWS for flash flood and the mitigation measures for flash floods anywhere.

Through these elements; monitoring and warning, preparedness, dissemination and communication, response, recovery, and review. Implementing this guidance will contribute to reduce the flash flood impacts at the study area.

The study further develops the flash flood early warning system guidance.

#### **7.4.2 Contribution to practice**

The study contributes to practice by bridging the gap in studies that review flash floods impacts in the Petra Region and how to reduce these impacts, recognition of a proper mechanism by which the role of early warning can simulate preparedness and proactive measures being implemented by the community.

The study contributes to practice by providing a useful tool in Petra Region for stakeholders, particularly for the government or the implementing agencies, helping ensure the success of reducing the flash flood risks by the development of FFEWSG. The new framework (guidance) designed and operationalised with some new components (i.e. monitoring and warning) and sub-components (i.e. recovery and review) that are missing from other frameworks. The above contributions reflect the novelty of this research.

This work is built on from earlier research by (Al-Weshah & El-Khoury, 1999, 2001) on Petra region who argue that flash flooding poses a serious risk to lives and properties in Petra Region under present conditions. Therefore; they recommend immediate actions to be taken to mitigate the flash flood risk at Petra Region such as: (i) to install an adequate rainfall-runoff monitoring system covering critical points in the watershed, and should be able to record short-duration rainfall-runoff events (ii) Flood-recording stations should be installed and rehabilitated at the major points in the watershed.

## **7.5 Limitation of Research**

This research has posed some challenges as experienced by many researchers. Although all of objectives were achieved. There were also problems of accessibility to governmental employees to interviews them to collect the required data because of lengthy procedures for allowing them to participate in interviews and to provide the required data. As well as the difficulty of interviewing the senior management staff and the Chairman and members of the Board of Commissioners of the PDTRA to obtain more accurate data; which could have helped to make this research more robust, from the information given by ordinary employees. Regardless, being able to interview ten experts helps to manage this research limitations and to ensure that objective outcomes were achieved. The persistence of the research thus ensured that this research is thoroughly carried out so that this research content can constitute as literature for future research in this area.

## **7.6 Further research**

The researcher strongly encourages future research focusing on identifying this concept and defining the interactions between local governmental institutions and the local community in concept of disaster risk reduction and building up resilience with the use of FFEWSG and the advantages of this concept in terms of community-based disaster risk reduction. It would be interesting to analyse the possible similarities and differences between the perspective of the local community and the other people from tourist and commerce sectors.

This study was based in Petra Region-Jordan. In line with this study, conducting a similar research in another city in Jordan or developing country would be a challenging research topic. This research employed the qualitative method as a method for developing guidance for flash flood early warning systems. As there are several other methods available, it would be interesting to conduct research by implementing other techniques, particularly by deploying a mixed-method (quantitative and qualitative), or quantitative method.

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## **Appendix (A)   Research methodology**

**Exploratory research:** The initial research into a hypothetical or theoretical idea. This is where a researcher has an idea or has observed something and seeks to understand more about it. An exploratory research project is an attempt to lay the groundwork that will lead to future studies, or to determine if what is being observed might be explained by a currently existing theory. Most often, exploratory research lays the initial groundwork for future research.

**Descriptive research:** Attempts to explore and explain while providing additional information about a topic. This is where research is trying to describe what is happening in more detail, filling in the missing parts and expanding our understanding. This is also where as much information is collected as possible instead of making guesses or elaborate models to predict the future - the 'what' and 'how,' rather than the 'why.'

**Explanatory research:** An attempt to connect ideas to understand cause and effect, meaning researchers want to explain what is going on. Explanatory research looks at how things come together and interact.

## Appendix (B) Interview Question for Users Group

<b>Name</b>		<b>Group</b>	USERS
<b>Qualifications</b>		<b>Participant Code</b>	
<b>Job Title</b>		<b>Age</b>	
<b>Organisation</b>		<b>Years of Experience</b>	
Q1.	How long have you been living Petra region?		
Q2.	How many flood events have you encountered? And at what times? Were these events occurring when tourism was at its peak?		
Q3.	What are the flood-prone areas in the Petra region? And what is the reason?		
Q4.	How the flooding, according to your perspective, affected the tourism and economic activities of the area?		
Q5.	What are the impacts of floods in the region (infrastructure, public and private properties ...etc.)?		
Q6.	Have there been any casualties in the past due to the floods? When? How was the number of deaths in each event?		
Q7.	When did you think the casualties were the highest and why?		
Q8.	Is there a cooperation and coordination between government institutions and local community, community-based organisations to reduce flood risk? What is the nature of this cooperation and coordination?		
Q9.	Are the local citizens aware of the actions to follow in case of flooding? What independent measures do they adopt?		
Q10.	From whom do they seek more information? Are you happy with this information and what adjustments are needed?		
Q11.	Are there any community awareness and training programmes on early warning on flooding?		
Q12.	Who in your opinion should train you or make more awareness?		
Q13.	Are the authorities lacking their commitment?		

## Appendix (C) Interview Question for Expert Group

<b>Name</b>			
<b>Participant Code</b>		<b>Qualifications</b>	
<b>Years of Experience</b>		<b>Job Title</b>	
<b>Organisation</b>		<b>Group</b>	

Q1.	How many flood events have you encountered? And at what times? Were these events occurring when tourism was at the peak?
Q2.	What are the flood-prone areas in the Petra region? And what is the reason?
Q3.	What are the main valleys in the Petra Region?
Q4.	Where are these valleys passing through? (i.e. residential, tourism, economic areas)
Q5.	These valleys constitute a major factor in flood occurrence in the region, through your experience, how do you explain that?
Q6.	Floods mainly leave casualties or damages; can you talk about these damages?
Q7.	When floods occur, preventive measures have to be taken to reduce the floods risk, what are these measures?
Q8.	What measures or tools does Petra Region Authority adopt to mitigate flood risk?
Q9.	What measures do the people adopt at property level? Do they over rely on regional measures?
Q10.	Is there a periodic review for these measures and improvement as appropriate need? What authorities are involved in this? Are there any joined up activities between different authorities and agencies?
Q11.	Petra Authority's contingency plan to deal with the flood risk (that may be annually reviewed) is an important component, of disaster risk management plan, how does (should) Petra Authority coordinate with concerned parties (within contingency plan) to reduce flood risk, such as civil defence, public security ...etc.?
Q12.	How does Petra Authority assess (should assess) the damages due to flooding? What are the processes followed? What are the equipment used?
Q13.	What is the Early Warning System (EWS) from your point view? How soon should the early warning be received for it to be meaningful? And what are the factors?
Q14.	What are the main components of the EWS?
Q15.	How would an EWS be an effective system and helps mitigating floods impacts?
Q16.	EWS that might be installed anywhere, to whom it should be directed? Local communities, local government ...etc.
Q17.	How could locals be aware of the actions that they have to do in case of flood?
Q18.	How do these systems deal with the nature of flash floods, such as suddenness, unpredictable?
Q19.	What are the current modelling methods related to floods?
Q20.	What are the current early warning systems related to floods?

## Appendix (D) A sample of Users Group Interviews

<b>Name</b>	<b>User_01</b>	<b>Age</b>	<b>32 years</b>
<b>Participant Code</b>	<b>User_01</b>	<b>Qualifications</b>	<b>Bachelor Degree in Engineering</b>
<b>Years of Experience</b>	<b>10 years</b>	<b>Job Title</b>	<b>Head of Community initiatives</b>
<b>Organisation</b>	<b>PDTRA</b>	<b>Group</b>	<b>Users</b>
Q1	How long have you been living Petra region? A1. 32 years, I born in Petra Region in 1982		
Q2	How many flood events have you encountered? And at what times? Were these events occurring when tourism was at its peak? A2. I encountered all floods events occurred during 1990s, the most important was in 1996, which considered as the most dangerous flood, as well as 1999 flood. In the current millennium, I encountered four flood events during the years 2003, 2010, 2011, 2012, and 2013, in which, the 2013 flood event was considered as the most dangerous one. None of these events was within the tourism peak.		
Q3	What are the flood-prone areas in the Petra region? And what is the reason? A3. The flood-prone areas are the three-major valleys areas in the region, Wadi Khalil, Wadi al-Saddir and Wadi Jelwakh and surrounding areas, due to the length of these wadis and the severity of its decline. These Wadis are also gathering in one Wadi (Wadi Musa) at the entrance of the Petra archaeological Park (PAP) causing disastrous results in the archaeological site.		
Q4	How the flooding, according to your perspective, affected the tourism and economic activities of the area? A4. There are direct and indirect flooding effects on the economic and tourist activities represented in: - Closing the archaeological site for a day or more, thus depriving the PDTRA and the local community from the proceeds of entering the archaeological site - Some houses and shops had been flooded and caused damages to the furniture or goods. - Some public and private properties such as cars and livestock exposed to risk of drift.		
Q5	What are the impacts of floods in the region (infrastructure, public and private properties ...etc.)? A5. Floods led to significant losses in infrastructure in the region, such as: 1-collapses in some roads and retaining walls 2-cracks in some houses residents 3-erosion and damage to large parts of the drainage systems and networks of drinking water and electricity networks. As for private property losses were: 1-collapses in the walls of houses 2-raid water for homes, which led to losses within them, such as furniture, electrical tools 3-cracks in some houses and the need to rehabilitate.		
Q6	Have there been any casualties in the past due to the floods? When? How was the number of deaths in each event? A6. Of the events that I have witnessed during the flood in 1996, he died a young man drowned in a flood, and I heard from my father that during the sixties of the last century occurred a great torrent claimed the lives of about 28 French tourists and a guide from the local community.		

Q7	<p>When did you think the casualties were the highest and why?</p> <p>A7. The biggest casualties were flooding in 1963 led to the deaths of 28 French tourists as well as a local guide in the Siq area, due to the absence of a dam in the beginning of Siq to reduce the impact of the flood on the archaeological area or conversion of the riverbed from the entrance of the archaeological area.</p>
Q8	<p>Is there a cooperation and coordination between government institutions and local community, community-based organisations to reduce flood risk? What is the nature of this cooperation and coordination?</p> <p>A8. There is a good coordination between government institutions during emergency time such as floods, where some institutions are working to raise public awareness of the possibility of flooding and guide citizens to take precautionary measures before it occurs. Relevant agencies are also working to reduce the impact of floods by putting soil barriers and clean the valleys and rain water drainage channels as well as preparedness of all cadres and the mechanics of concerned authorities for intervention at the appropriate times during the flood period.</p>
Q9	<p>Are the local citizens aware of the actions to follow in case of flooding? What independent measures do they adopt?</p> <p>A9. There are some messages and instructions, which broadcasts to citizens through various means to raise awareness of the methods used and that must be followed in the event of flooding. There are individual measures undertaken by some locals like putting sand barriers to divert streams of water from their homes or barns for sheep and the like.</p>
Q10	<p>From whom do they seek more information? Are you happy with this information and what adjustments are needed?</p> <p>A10. Through the media and weather forecasts. And the level of satisfaction to some extent</p>
Q11	<p>Is there are any community awareness and training programmes on early warning on flooding?</p> <p>A11. There are a few awareness programs, but limited in either lectures per day in schools or workshops to raise awareness of the flooding risk.</p>
Q12	<p>Who in your opinion should train you or make more awareness?</p> <p>A12. All concerned authorities for flood disaster management, particularly the Civil Defence, Petra Governorate, and PDTRA</p>
Q13	<p>Are the authorities lacking their commitment?</p> <p>A13. There are acceptable commitments but sometimes the lack of equipment, lack of sufficient number and appropriate type of machinery may limit the effective intervention to reduce the impact of floods in the region.</p> <p>In addition to the absence of major projects such as water harvesting projects to take advantage of rain water and reduce its impact</p>



## Appendix (E) A sample of Expert Group Interviews

<b>Name</b>	<b>Expt_06</b>	<b>Age</b>	<b>48 years</b>
<b>Participant Code</b>	<b>Expt_06</b>	<b>Qualifications</b>	<b>PhD in Geology and High Diploma in Disaster Risk Management</b>
<b>Years of Experience</b>	<b>&gt;20 years</b>	<b>Job Title</b>	<b>Disaster Risk Management Expert</b>
<b>Organisation</b>	<b>Private</b>	<b>Group</b>	<b>Experts</b>
Q1	How many flood events have you encountered? And at what times? Were these events occurring when tourism was at the peak? A1. Recently, two events per year, this happening from Nov-Apr, luckily; the tourism at that time is not at the peak.		
Q2	What are the flood-prone areas in the Petra region? And what is the reason? A2. Typically, the low land that has no capacity to absorb the water from the catchment area		
Q3	What are the main valleys in the Petra Region? A3. Wadi Siyagh, Wadi Ad Deir, Wadi Numeir, Wadi Mousa, Wadi Turkaniya, Wadi Al Mahfus, Wadi Mataha, Wadi Mudhlim, Wadi Alssadir, Wadi Jelwakh and Wadi Magir,		
Q4	Where are these valleys passing through? (i.e. residential, tourism, economic areas) A4. It passing Residential and Tourism areas		
Q5	These valleys constitute a major factor in flood occurrence in the region, through your experience, how do you explain that? A5. Since all these valleys are connected, the final drainage will become major and affect the flood		
Q6	Floods mainly leave casualties or damages; can you talk about these damages? A6. Please see the attached table that summarize the inventory of flash flood events in the area.		
Q7	When floods occur, preventive measures have to be taken to reduce the floods risk, what are these measures? A7. Permanent monitoring of the risk of flooding, Setting up one or several information and flood warning centres for the population, Issuing regulations banning building, residing in, and access to identified risk zones and implementing specific protective systems such as alarm signals, Building and developing infrastructure that will prevent, avoid or limit floods and protect the population, Planning the evacuation of the population likely to be at risk, and instructing them on how to behave in case of a flood and Forming well trained and equipped management and rescue teams.		
Q8	What measures or tools does Petra Region Authority adopt to mitigate flood risk? A8. No Comments		
Q9	What measures do the people adopt at property level? Do they over rely on regional measures? A9. Divergent channels, small scale dams and plantation, there is a sort of confidence on the regional measures.		
Q10	Is there a periodic review for these measures and improvement as appropriate need? What authorities are involved in this? Are there any joined up activities between different authorities and agencies? A10. Not really, since still these authorities working on ad hoc basis		
Q11	Petra Authority's contingency plan to deal with the flood risk (that may be annually reviewed) is an important component, of disaster risk management plan, how does (should)		

	<p>Petra Authority coordinate with concerned parties (within contingency plan) to reduce flood risk, such as civil defence, public security ...etc.?</p> <p>A11. It should be known that the effectiveness operational EWS will serve as an important tool for all responders (PDTRA, Ministry of Interior, Civil Defence and others) for coordinating the efforts and have lead time for responding, so regular consultations and discussions need to be maintained.</p>
Q12	<p>How does Petra Authority assess (should assess) the damages due to flooding? What are the processes followed? What are the equipment used?</p> <p>A12. Whether by visual observations or reports based on (on-ground) assessment, after documenting theses damages, the authority compensates the people if there are no remarks on the permissions for construction and as per the available budget</p>
Q13	<p>What is the Early Warning System (EWS) from your point view? How soon should the early warning be received for it to be meaningful? And what are the factors?</p> <p>A13. EWS is a system that issues forecasts upon which is acted, its primary objectives are to increase the preparedness of the authorities and population for flash floods, to plan emergency and risk communication procedures and to strengthen the institutional capacity in order to effectively operate an EWS and communicate the warning.</p>
Q14	<p>What are the main components of the EWS?</p> <p>A14. Telemetered rain gauges, Rainfall forecasting, Flood wave modelling, assessed model performance, Simulating scenarios, Strategy for issuing and responding to warnings and Technical capacity building</p>
Q15	<p>How would an EWS be an effective system and helps mitigating floods impacts?</p> <p>A15. Warnings can be issued based on pre-defined thresholds of meteorological observations and/or forecasts, runoff, flow, flood depth or flood extent. Crucial for the operational use of EWS are the steps taken between the issuing of a warning and the start of actual actions on the ground. The period between the warning and the actual event is called the lead time, during this lead time the local communities and responders can act as per the plans set based on participatory approach.</p>
Q16	<p>EWS that might be installed anywhere, to whom it should be directed? Local communities, local government ...etc.</p> <p>A16. It should be directed to the local communities and local government as end-users and direct beneficiaries and to the local governments as operator.</p>
Q17	<p>How could locals be aware of the actions that they have to do in case of flood?</p> <p>A17. The continuous awareness raising and consultations with all concerned stakeholders</p>
Q18	<p>How do these systems deal with the nature of flash floods, such as suddenness, unpredictable?</p> <p>A18. Considering that errors might occur, "working with uncertainty" is an important skill that needs to be enhanced by operators and decision-makers. The choice on the expected level of accuracy - linked to what level of risk is acceptable - is thus not only a technical question, but also a social/management question.</p>
Q19	<p>What are the current modelling methods related to floods?</p> <p>A19. From the historical development of the hydrological models, modelling approaches can be classified as black-box models, physically based models, and conceptual models... Then conceptual models are classified as lumped models, which are represented by spatially averaged watershed characteristics, and distributed models that incorporate the spatial variability. A semi-distributed model may adopt a lumped representation for individual sub-catchments</p>

Q20	<p>What are the current early warning systems related to floods?</p> <p>A20. In the country no one, but in the region there a system implemented in the Sinai Peninsula (Egypt).</p>
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## Appendix (F) Interview for validation guidelines

### Interview for Validation Guidelines

#### Early Warning System Guidance to Mitigate Flash Flood Impacts in Petra Region

##### Purpose of the interview:

1. To validate findings from semi-structured interviews

##### Section A: Flood events and Impacts

###### Flood events: events, prone areas

1. Flood events occurred in Petra Region are:

Event No	Year	Event No	Year	Event No	Year
1	1963	4	2001	7	2011
2	1994	5	2004	8	2012
3	1996	6	2010	9	2013

Do you think that Petra Region has encountered to these events between 1963-2015?

2. Flood-prone areas are: (1) Valleys (Wadi's) and their boundaries (2) Water streams (3) Low areas (4) Buildings close to valleys and water streams. What do you think about these areas?

###### Flood impacts: effects, impacts and casualties

3. Flash flood events have left many effects at the tourism, economic, and social sectors, besides the effects at the infrastructure in study area such as: roads, retaining walls, sewage system, water and electricity networks, rainwater drainage systems, and irrigation canals, besides the impacts at the local community properties such as houses, vehicles, furniture, and electrical appliances. What is your opinion about the findings?
4. Floods left 20-29 deaths in 1963, one death in 1996, and three deaths in 2001, do you agree with these casualties?

##### Section B: Preparedness and mitigation

###### Preparedness: prevention measures, independent measures, risk knowledge, training and awareness, and contingency plan

5. Procedure that might be followed in case of floods is quietly known by local citizens but could be enhanced by workshops, training, and awareness campaigns. Do you agree with this result?

6. Most of citizens in Petra Region have undertaken independent measures to protect themselves and their properties from floods. Do you agree that these independent measures are truly undertaken?
7. PDTRA has its contingency plan, it should coordinate with concerned parties to reduce flood risk by:
  - Sharing data and information.
  - Organizing joint awareness campaigns.
  - Undertaking exercises and drills.
  - Developing an early warning system
  - Reviewing and updating emergency plan
  - Lessons learned
  - Evacuation plans
  - Providing potential assistance.

How do you find these aspects of coordination contribute to reduce flood risks?

**Mitigation: measures, revision and improvement, and assessment**

8. Mitigation and prevention measures (structural and non-structural) must be adopted by Local government to reduce flash floods impacts such as:
  - Levees, storage ponds, pumping stations, water canals
  - Flood diversion and terracing
  - Afforestation
  - Water harvesting in small dams, pools, valleys
  - Secure valleys' borders and construct obstacles
  - Developing infrastructure
  - Restore valleys to their natural courses
  - Invest in flood defences
  - Early warning systems
  - Training, awareness, drills and exercises
  - Contingency plan
  - Land use planning and sensitive risk land use planning
  - Risk dissemination
  - Monitoring flood risks

Do you agree with these measures?

## **Section C: Early Warning Systems**

### **Early warning systems and their effectiveness**

9. EWS is an effective system if it has: (1) reliable forecast or measurements (2) clear threshold for warning and alert (3) excellent system of communication (4) preparedness and drills. What do you think about these requirements?
10. EWS is an effective system when: (1) it gives enough lead time to enable responders to act as per plans set based on participatory approach and implement an evacuation if needed (2) it follows and applies the main component the EWS, trains others how to respond and communicate well with it, and what they should do when it is activated. How do you find these factors relevant to EWS effectiveness?

**Thank you very much for your valuable time**

## Appendix (G) Inventory of flash flood events in Petra Region

ID	Dates	Description of the flash flood event
1	April 1963	<p><b>Casualties:</b> About 20 tourists lost their lives (exact number varies depending on source between 18-22-27).</p> <p><b>Damages:</b> Wadi el Yutim dam was destroyed during that flood</p> <p><b>Water depths:</b> Eyewitnesses stated that the flood water depth was about 10 m in some areas of the Siq passage.</p> <p><b>Further description:</b> Flood water to flow from all wadis into the main wadi upstream of the Siq. The flood carried a huge sediment load of loose silt and sand which blocked most of the hydraulic structures in the wadi. The dam at the entrance of the Siq was filled with sediment; consequently, flood water overtopped the dam and entered the Siq instead of being diverted through the tunnel of Wadi Al-Mudhlim.</p> <p><b>Source of information:</b> El-Weshah and El-Khoury (1999)</p>
2	25/11/1968	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> N/A</p> <p><b>Water depths:</b> observed peakflow 1,79 m<sup>3</sup>/s; observed flood volume 5,3 m<sup>3</sup>*10<sup>3</sup>; 21 mm of rainfall</p> <p><b>Further description:</b> N/A</p> <p><b>Source of information:</b> Used for calibration of the model in El-Weshah and El-Khoury (1999);</p>
3	10/03/1970	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> N/A</p> <p><b>Water depths:</b> observed peakflow 2,18 m<sup>3</sup>/s; observed flood volume 4 m<sup>3</sup>*10<sup>3</sup>; 46 mm of rainfall</p> <p><b>Further description:</b> N/A</p> <p><b>Source of information:</b> Used for calibration of the model in El-Weshah and El-Khoury (1999);</p>
4	14/01/1974	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> N/A</p> <p><b>Water depths:</b> observed peakflow 0,41 m<sup>3</sup>/s; observed flood volume 4,3 m<sup>3</sup>*10<sup>3</sup>; 22,6 mm of rainfall</p> <p><b>Further description:</b> Used for calibration of the model in El-Weshah and El-Khoury (1999);</p>
5	1991	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> FF washed away two culverts upstream of the Siq and caused a serious problem for tourists</p> <p><b>Water depths:</b> Although the flood water did not enter the Siq, Traces of high water within Wadi Al-Matahah (to which the diversion tunnel of Wadi Al-Mudhlim discharges) indicated that the water level reached an elevation of more than 12 m above the wadi bed.</p> <p><b>Further description:</b> Flood flow made crossing the wadi within the archaeological area very difficult. The monument of "Qasr El-Bint" at a site downstream of the Siq was also flooded</p> <p><b>Source of information:</b> El-Weshah and El-Khoury (1999)</p>
6	April 1994	<p><b>Casualties:</b> None</p>

		<p><b>Damages:</b> Small old house damaged, cracks on main and sub-roads, damages on flora and fauna, bridges, water and power networks</p> <p><b>Water depths:</b> 4.2 m</p> <p><b>Further description:</b> The Siq entrance area was flooded and tourists had to be rescued</p> <p><b>Source of information:</b> El-Weshah and El-Khoury (1999)</p>
7	November 1996	<p><b>Casualties:</b> One person died</p> <p><b>Damages:</b> The Siq entrance area was flooded and tourists had to be rescued</p> <p><b>Water depths:</b> 5.4 m</p> <p><b>Further description:</b> The Siq entrance area was flooded and tourists had to be rescued</p> <p><b>Source of information:</b> El-Weshah and El-Khoury (1999)</p>
8	April 2001	<p><b>Casualties:</b> 3 people died</p> <p><b>Damages:</b> Bridges, roads, private company machinery</p> <p><b>Water depths:</b> 7.6 m</p> <p><b>Further description:</b> No rain was seen in Wadi Mousa; Heavy rainfall in the east caused the flash flood. FF came down in two separate waves from El Hai in the mountains</p> <p><b>Source of information:</b> -</p>
9	15/01/2004	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> FF in Petra. Treasury flooded</p> <p><b>Water depths:</b> 3.4 m</p> <p><b>Further description:</b> FF in Petra. Treasury flooded;</p> <p><b>Source of information:</b> Video on YouTube  <a href="http://www.youtube.com/watch?v=nI0-J00XcZ8&amp;feature=channel">http://www.youtube.com/watch?v=nI0-J00XcZ8&amp;feature=channel</a>  <a href="http://www.youtube.com/watch?v=CQeOJJ3nzJ8&amp;feature=channe">http://www.youtube.com/watch?v=CQeOJJ3nzJ8&amp;feature=channe</a></p>
10	15/12/2005	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Airport Aqaba closed for 2 weeks</p> <p><b>Water depths:</b> 2.3 m</p> <p><b>Further description:</b> Big FF, airport Aqaba closed for 2 weeks; water of Wadi Araba was brown for 2 months because of sediment load. No safe drinking water in Aqaba.</p> <p><b>Source of information:</b> Interview with PAP guide Marwan Qadafi</p>
11	2009	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Petra was flooded, some damages in the infrastructure</p> <p><b>Water depths:</b> 1.8 m</p> <p><b>Further description:</b> Petra was flooded again in 2009</p> <p><b>Source of information:</b> -</p>
12	18/01/2010	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Cracks in retaining walls and roads, some houses were flooded and have some damages</p> <p><b>Water depths:</b> 2.2 m</p> <p><b>Further description:</b> Water flowing through the wadi bed upstream; did not reach Petra</p> <p><b>Source of information:</b> Video from Dr. Mohamed Alfarajat</p>
13	18/01/2010-20/01/2010	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Cracks in retaining walls and roads, some houses were flooded and have some damages</p>



		<p><b>Water depths:</b> 2.2 m</p> <p><b>Further description:</b> Raining off and on whole day; Siq is flooded just before sunset.</p> <p><b>Source of information:</b> Video on YouTube  <a href="http://www.youtube.com/watch?v=7H9irnc4aXE&amp;feature=related">http://www.youtube.com/watch?v=7H9irnc4aXE&amp;feature=related</a></p>
14	26/12/2010	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> About 3 retaining walls collapsed and cracks in roads, some houses were flooded and have massive damages</p> <p><b>Water depths:</b> about 50cm</p> <p><b>Further description:</b> FF in Petra;</p> <p><b>Source of information:</b> Video on YouTube  <a href="http://www.youtube.com/watch?v=GOXAU8dnUSw&amp;feature=related">http://www.youtube.com/watch?v=GOXAU8dnUSw&amp;feature=related</a></p>
15	4/04/2011	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Petra was flooded, some damages in the infrastructure</p> <p><b>Water depths:</b> 1.95 m</p> <p><b>Further description:</b> After 30 mins of heavy rain fall, the Authorities started to evacuate Petra. Siq is closed. A flash flood appeared without indication</p> <p><b>Source of information:</b> Video on YouTube  <a href="http://www.youtube.com/watch?v=w05ECpSnSO4">http://www.youtube.com/watch?v=w05ECpSnSO4</a>  <a href="http://www.youtube.com/watch?v=mrnzqMrv6s&amp;feature=related">http://www.youtube.com/watch?v=mrnzqMrv6s&amp;feature=related</a></p>
16	31/01/2013- 03/02/2013	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Retaining walls, roads, private properties estimated by \$5M-\$7M</p> <p><b>Water depths:</b> 2.15 m</p> <p><b>Further description:</b> Main city Wadi Mousa was flooded from the main Valleys, raining was for about 4 days with high intensity.</p> <p><b>Source of information:</b> Petra Authority, and self-observation</p>
17	08/02/2013	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> Some damages in the infrastructure, water channels,</p> <p><b>Water depths:</b> 30 cm in Petra and 1-1.5m in Wadi Mousa main valleys</p> <p><b>Further description:</b> Petra Treasury was flooded and tourists were evacuated. Many retaining walls were collapsed, soil erosion led to close main street in Wadi Mousa and Tabybah (small town near Wadi Mousa)</p> <p><b>Source of information:</b> Petra Authority, Video on YouTube  <a href="https://www.youtube.com/watch?v=vt_aJdWZAdA">https://www.youtube.com/watch?v=vt_aJdWZAdA</a></p>
18	20/11/2013	<p><b>Casualties:</b> None</p> <p><b>Damages:</b> More than 42 retaining walls collapsed cracked, or washed away, large fall in a road as a result of cracked retaining wall, houses were flooded and their furniture were damaged</p> <p><b>Water Depths:</b> 1.5-2.5 m</p> <p><b>Further description:</b> It rained 5km away and the side of the siq exploded with water.</p> <p><b>Source of information:</b> Petra Authority, Video on YouTube  <a href="https://www.youtube.com/watch?v=AszqSlyDzec">https://www.youtube.com/watch?v=AszqSlyDzec</a></p>

## Appendix (H) Publications

### Journal Papers

Alhasanat, H. (2014). Flash Flood Assessment for Wadi Mousa City-Jordan. *Procedia Economics and Finance*, 18(0), 675-683. doi: [http://dx.doi.org/10.1016/S2212-5671\(14\)00990-3](http://dx.doi.org/10.1016/S2212-5671(14)00990-3)

Alfarajat, M.; Alhasanat, H.; Diabat A.; Ibweni M.; Shawaqfeh J. (2014), Using gravity in visualizing sedimentary basin; a step to locate VES locations to enable investigating groundwater potentials in promising sites in Baida sedimentary basin in Petra – Jordan , *Jordan Journal of Civil Engineering*.

Alfarajat, M.; Alhasanat, H.; Atteyat, N.; Al Jahed, N.; Khataibeh, J. (2014). Integrated gravity/resistivity methods to investigate groundwater potentials in Baida sedimentary basin in Petra – Jordan, *Journal of Geophysics and Engineering*.